NCE LIBRARY

43

NOV - 6 1933

Vol. 60 NOVEMBER, 1933 No. 8

Bulletin

of the

Torrey Botanical Club

Editor

Bernard O. Dodge

Associate Editors

John Hendley Barnhart
Albert Francis Blakeslee
Cornelia Lee Carey
Frank Earl Denny
Alexander William Evans
Henry Allan Gleason
Arthur Harmount Graves
Alfred Gundersen
George Tracy Hastings
Tracy Elliot Hazen
Marshall Avery Howe
Louis Otto Kunkel
Michael Levine
Arlow Burdette Stout
Sam F. Trelease
William H. Weston, Jr.

CONTENTS

Arthur Hollick, February 6, 1857–March 11, 1933 ..... *Marshall A. Howe* 537

The curvature, symmetry and homologies of the sporocarps of Marsilea and Pilularia ..... *Duncan S. Johnson* 555

The constancy of cultural characters and pathogenicity in variant lines of Ustilago zeae ..... *E. C. Stakman, L. J. Tyler and G. E. Hafstad* 565

The germination and growth of Peltandra virginica in the absence of oxygen ..... *Thomas I. Edwards* 573

On the vaccination of the tobacco plant against Thielaviopsis basicola ..... *Carlo Arnaudi* 583

Index to American Botanical Literature 598

Published for the Club monthly except
July, August, and September

by

GEORGE BANTA PUBLISHING COMPANY, MENASHA, WISCONSIN

Subscription price $5.00 per year

Entered as Second Class Matter at the Post Office at Menasha, Wisconsin
Accepted for mailing at special rate of postage provided for in the act of February 28, 1925, embodied in paragraph 4, section 412, P. L. and R., authorized July 23, 1928.

THE TORREY BOTANICAL CLUB

President
ALBERT FRANCIS BLAKESLEE, PH.D., D.Sc.

Vice-Presidents
HENRY ALLAN GLEASON, PH.D.
ROGER PHILIP WODEHOUSE, PH.D.

Secretary
FORMAN T. McLEAN, PH.D.
New York Botanical Garden, Bronx Park, New York, N.Y.

Treasurer
MRS. R. A. HARPER, M.A.
Schermerhorn Hall, Columbia University, New York, N.Y.

Editor
BERNARD O. DODGE, PH.D.

Bibliographer
JENNIE S. DODGE

MEETINGS

Meetings twice each month from October to May, inclusive: the first Tuesday at 8:15 P.M., at the American Museum of Natural History or at Columbia University; the third Wednesday at 3:30 P.M., in the Museum Building of the New York Botanical Garden, Bronx Park, New York, N.Y.

PUBLICATIONS

All subscriptions and other business communications relating to the publications of the Club should be addressed to the Treasurer, Mrs. R. A. Harper (mail address, Schermerhorn Hall, Columbia University, New York, N.Y.). Matters relating to advertisements and circulation should be referred to Dr. Michael Levine, Montefiore Hospital, New York, N.Y. All communications regarding exchanges should be referred to the Exchange Committee, consisting of the Librarian of the Columbia University and the Librarian of the New York Botanical Garden.

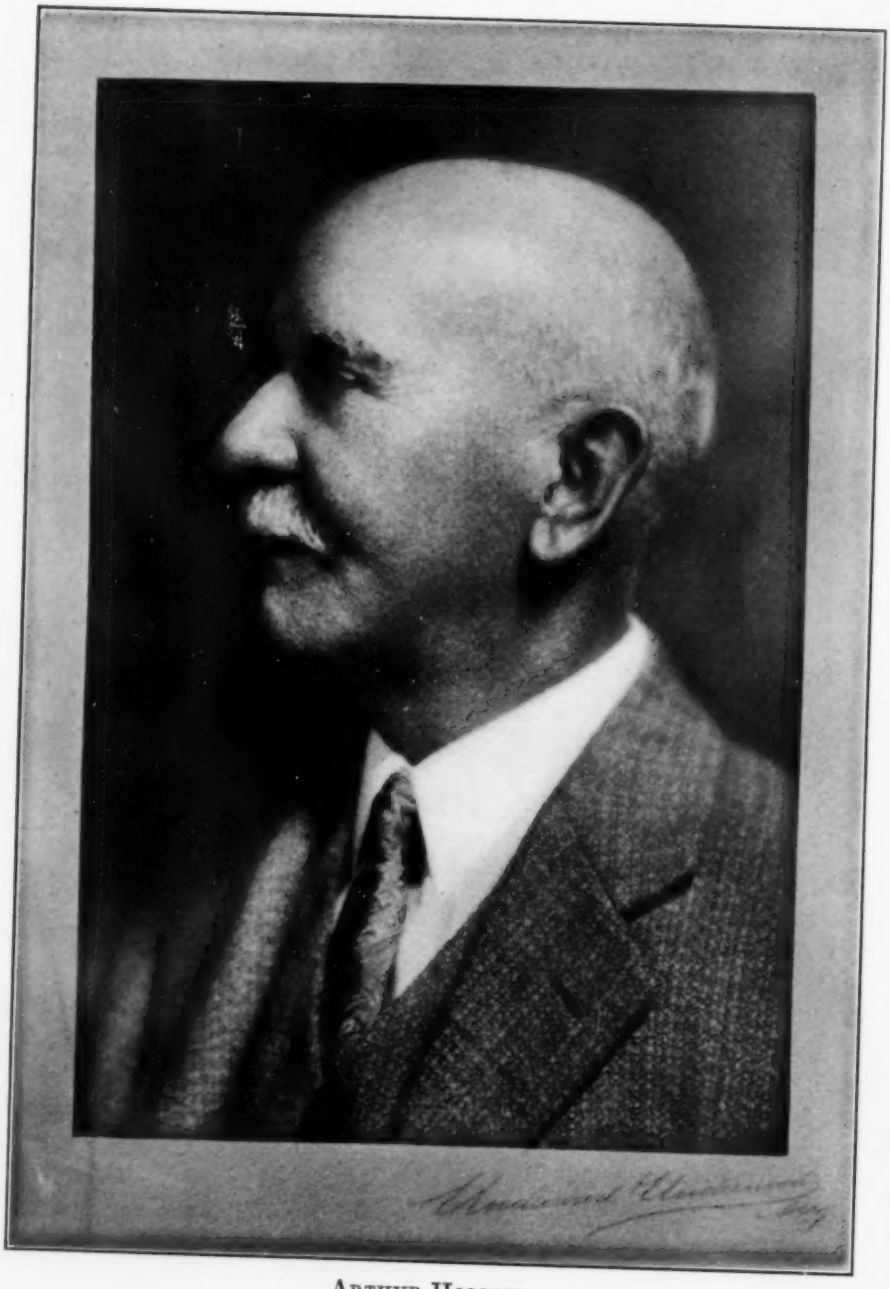
Bulletin. Established 1870. Monthly, except during July, August, and September. Price, $6.00 a year; single numbers 75 cents. Of former volumes, only 24–56 can be supplied separately; certain numbers of other volumes are available, but the entire stock of some numbers has been reserved for the completion of sets. Manuscripts intended for publication in the BULLETIN should be addressed to Dr. B. O. Dodge, New York Botanical Garden, Bronx Park, New York, N.Y. The editors may accept papers up to 20 pages in length, with illustrations and tabular matter generally not exceeding twenty per cent of that amount. Longer and more copiously illustrated papers, however, may be published if the excess pages, illustrations, and tabular matter are paid for by the contributors.

Torreya. Bimonthly, established 1901. Price, $1.00 a year. Manuscripts intended for publication in TORREYA should be addressed to Mr. George T. Hastings, Editor, 258/ Sedgwick Ave., New York, N. Y.

Memoirs. Occasional, established 1889.

Preliminary Catalogue of Anthophyta and Pteridophyta within 100 miles of New York City, 1888. Price, $1.00.

Reprints. Contributors of articles accepted for publication in the BULLETIN should order reprints, if desired, when they return galley proofs to the editor. They may be ordered through the editor from the George Banta Publishing Company, the contributor paying for all his reprints. A schedule of rates is sent with galley proof.



ARTHUR HOLLICK

(1857–1933)

UNIV. OF MICH.

ARTHUR HOLLICK

February 6, 1857—March 11, 1933

MARSHALL A. HOWE

WITH PORTRAIT

Although maintaining his youthful vigor in a large measure up to the last week of his life, Dr. Arthur Hollick, rounding out his three score and sixteen years, was, to many members of The Torrey Botanical Club, a link with the past. In company with his distinguished lifelong friend, Nathaniel Lord Britton, he joined the Club in October, 1877, when both were beginning their junior year in the School of Mines of what was then Columbia College. In his very interesting "Torrey Botanical Club Reminiscences," read on the occasion of the semi-centennial of the Club in 1917 and published in volume 17 of the *Memoirs*, he tells of his early habit of attending meetings of the Club in the City, missing the last (9 P.M.) boat to Staten Island, catching the midnight train on the Central Railroad of New Jersey, getting off at the Bergen Point Station, walking three quarters of a mile to the shore of the Kill van Kull, waking up the rowboat ferryman, and reaching home at Port Richmond about 1:30 A.M.! That was in the days when the election of a woman to membership in the Club would have been "unthinkable"! The enthusiasm for scientific activities thus manifested in his youth was destined to persist. On January 24, less than seven weeks before his passing, he had returned, with Mrs. Hollick, from a month's visit to Cuba, where he had engaged, in company with Brother León of the Colegio de la Salle, in an investigation of the fossil flora of that island, with the aid of a grant from the O. C. Marsh Fund of the National Academy of Sciences. During his month in Cuba, he visited localities in all six of its provinces, traveling more than one thousand miles, partly on horseback, and triumphantly bringing back to New York a large collection of excellently preserved plant remains, the critical study of which must now be given to others.

[Charles] Arthur Hollick was born at New Brighton, Staten Island, New York, on February 6, 1857, the son of Dr. Frederick and Eleanor Eliza (Bailey) Hollick. Both father and mother were English, coming to the United States in 1842 and settling on Staten Island. His father, left an orphan at four years of age, was thrown on his own resources

[THE BULLETIN FOR OCTOBER (60: 465-536) WAS ISSUED OCTOBER 2, 1933]

when only thirteen, went from Claverdon to Birmingham, apprenticed himself to a silversmith, studied nights and attended lectures at the Mechanics Institute, receiving at seventeen a silver medal for proficiency in mathematics. At twenty-two he received the degree of M.D. from the University of Edinburgh. After coming to the United States he taught and lectured extensively on medical subjects, and was the author of several popular books on human anatomy and physiology. The elder Hollick was also a naturalist "of the old school," leaving collections of plants and minerals that are now in the possession of the Staten Island Institute of Arts and Sciences.

After preparation in private schools of New York and Wiesbaden, Germany, Arthur Hollick, then Charles Arthur Hollick, entered the School of Mines of Columbia College and on graduation in 1879 in the course in geology and paleontology received therefrom the degree of Bachelor of Philosophy. It is noteworthy that in 1879, the year of his graduation, "The Flora of Richmond County, New York," a pamphlet of thirty-six pages by Arthur Hollick of Port Richmond and N. L. Britton of New Dorp made its appearance. Hollick's first position, held for a short time, appears to have been that of Superintendent of the Mexican Mine in Mariposa County, California. In February, 1881, he was appointed Assistant Sanitary Engineer of the Board of Health of the City of New York, which consisted then of what is now the Borough of Manhattan and a part of what is now the Borough of the Bronx. During the ten-year period of his incumbency of this office, he was concerned especially with problems connected with factory vapors, water supply, sewerage, plumbing, ventilation, etc. On his inspection list during the process of construction were several important buildings, such as the old Madison Square Garden, the Mills Building, the Navarro Flats, etc. On one occasion, when the Board of Health was short-handed, as many as one thousand unfinished buildings were on his inspection list at one time. During this decade of his life, he was also a consultant or expert assistant in solving various sanitary problems of other municipalities, such as Brooklyn, Long Island City, Mount Vernon, Poughkeepsie, Elmsford, and certain communities on Staten Island. As late as 1910, he was asked to report on the geologic conditions affecting the water supply of Staten Island.

That Hollick's interest in plants was maintained during the ten years that he was primarily engaged in sanitary engineering is evidenced by the publication of notes and reviews in the BULLETIN OF THE TORREY BOTANICAL CLUB, especially perhaps by the several lists of "Additions and New Localities" to the Hollick and Britton "Flora of Richmond

County" [Staten Island]. His interest is further attested by the fact that he served as Recording Secretary of the Club for the years 1883 to 1888, inclusive, and later as an Associate Editor of the BULLETIN. His more strictly and actively scientific career began with his appointment in 1890 as Fellow in Geology in Columbia College, to which position he was reappointed in 1891. He had previously acted from time to time as a private assistant to Professor J. S. Newberry and had made the drawings for many of Professor Newberry's published papers on fossil plants and fishes. In the college year 1891–92 he carried on a part of the lecture work of Professor Newberry, then incapacitated by illness, and in 1892 he was appointed Assistant in Geology. In that year he conducted the summer school of geology for the third-year students in mining engineering at the Lake Superior mines. This is said to have been the first attempt at practical field geology in the history of the School of Mines. In 1893 his title was changed to Tutor in Geology. At this time and later he gave instruction in drawing to Columbia college students in various courses in geology and paleontology. During this period he was carrying on research work that was accepted by the Columbian (now George Washington) University in fulfilment of the requirements for an advanced degree and in 1897 the degree of Doctor of Philosophy was conferred upon him by that institution. In 1900, Dr. Hollick conducted the Summer School of Geology at Canyon City, Colorado.

Another epoch in the career of Dr. Hollick began on July 1, 1901, when (at the same time as the writer of the present sketch) he became an Assistant Curator of The New York Botanical Garden, which meant that he was placed in charge of the collections of fossil plants, with a considerable amount of his time free for research. The Garden's collection of fossil plants was at that time essentially non-existent, but by a previous agreement between the Board of Managers of the Garden and the Trustees of Columbia University, the paleobotanical collections of the University were soon deposited in the Museum Building of the Garden, under terms of agreement similar to those under which the general herbarium of Columbia University had already been deposited at the Garden. The Columbia collection of fossil plants consisted of several thousand specimens, including the types of many species described by Professor Newberry. In 1901, Dr. Hollick spent a month in Maryland, in coöperation with the Maryland Geological Survey, collecting fossil plants that were described by him in 1906 in the "Pliocene and Pleistocene" volume of the Maryland Geological Survey. In 1903 he spent four months in Alaska under the auspices of the United States Geological Survey,

exploring the Yukon River Valley, going down the river by canoe from Dawson to Anvik, a distance of more than 1000 miles and bringing back to Washington 1800 pounds of specimens. Later, he was in residence in Washington for two periods of six months each, studying the Alaskan material obtained on this trip and preparing reports upon it for the United States Geological Survey. His general scientific activity in the period from 1901 to 1914 is reflected in numerous titles in the bibliography published below. Noteworthy are his articles on "Palaeobotany" in volume 13 of The New International Encyclopaedia (1903) and on "Palaeobotany or Fossil Botany" in volume 11 of the Encyclopaedia Americana (1904).

Arthur Hollick was one of the prime-movers in the establishment of the Natural Science Association of Staten Island (later the Staten Island Association of Arts and Sciences and finally the Staten Island Institute of Arts and Sciences). With N. L. Britton and William T. Davis, he signed the call for a meeting on Nov. 12, 1881, to organize a scientific society on Staten Island. At this organization meeting he was elected corresponding secretary, a position afterwards merged with that of secretary, to which post he was elected in January, 1893. From 1883 to 1888, he was co-editor of the Proceedings of the Association with William T. Davis, and from 1888 to 1892 he was the sole editor. It is said that he attended the meetings of the Association, rain or shine, and that from the initial meeting in November, 1881, to November, 1893, he missed only two meetings, one on account of illness and one by reason of being in the Rocky Mountains region at the time. In the reorganization and incorporation under the name of the Staten Island Association of Arts and Sciences in 1904 and 1905, Dr. Hollick became Recording Secretary and a member of the Board of Trustees. In November, 1913, he tendered his resignation as a member of the curatorial staff of The New York Botanical Garden, effective December 31, to accept the position of Curator-in-Chief of the Public Museum of the Staten Island Association of Arts and Sciences, a title that soon thereafter was changed to that of Director. In resolutions expressing regret at his withdrawal, the Scientific Directors of the Garden recognized his "enthusiasm and ability" and his noteworthy investigations "highly creditable to himself and to the Garden" and voiced a request that the Board of Managers should designate him as Honorary Curator of Fossil Plants, a request with which the Managers soon complied. On May 17, 1919, Dr. Hollick resigned the directorship of the Staten Island Museum and in 1921 he was again a member of the curatorial staff of The New York Botanical Garden, with the title of Paleobotanist, a position that he held until his death on March 11, 1933, though on July 1, 1932, his title was changed to Research Associate in Paleontology.

In 1926, Dr. Hollick spent a large part of the month of March in Porto Rico. The results of his investigations there were published in 1928 in volume 7 of the Scientific Survey of Porto Rico and the Virgin Islands, his report on the Paleobotany of Porto Rico covering 228 pages and including 38 plates. Four years previously he had published "A review of the fossil flora of the West Indies, with descriptions of new species," the newly described forms being mostly from Porto Rico, Trinidad, and Cuba. Other important paleobotanical contributions of Dr. Hollick during the last decade of his life are "The flora of the Saint Eugene silts, Kootenay Valley, British Columbia," 1927, and "The Upper Cretaceous flora of Alaska," 1930, the latter with 87 plates. What may fairly be considered Hollick's *magnum opus*, his report on "The Tertiary flora of Alaska," remains unpublished in the files of the United States Geological Survey in Washington. This consists of 723 typewritten pages and 121 plates.

In addition to the scientific organizations already mentioned, Dr. Hollick was a charter member and for several years Treasurer of the Botanical Society of America, a Fellow of The New York Academy of Sciences, the Geological Society of America, and the American Association for the Advancement of Science.

Any record of the life and career of Arthur Hollick would be incomplete without some record of his activities as a citizen interested in good government. From 1886 to 1892 he was a member of the Board of Health of the village of New Brighton on Staten Island, being especially active in securing frequent analyses of drinking water, in the establishment of a sewerage system, and in abating the smoke nuisance caused by factories in Bayonne, N. J. Governor Black, in 1897, appointed him a member of Board of Park Commissioners for Richmond County, of which he was made vice-president and later (1901–1904) president. In 1900 he helped to organize the Richmond Borough branch of the Citizens Union and was one of the vice-presidents of the Fusion meeting that resulted in the nomination of Seth Low, President of Columbia University, as Fusion candidate for Mayor of Greater New York, and he was a member of the special committee that notified Mr. Low of his nomination. After the election of Mayor Low in 1901, he remained active in the Citizens Union organization. In 1906, Mayor George B. McClellan appointed him a member of the Board of Education of the City of New York.

On September 19, 1881, Arthur Hollick married Adeline Augusta Talkington. A golden wedding celebration was held on Staten Island in September, 1931. Besides his widow, Dr. Hollick leaves two daughters, Eleanor Adeline (Mrs. Eleanor H. Wells) and Grace Eaton (Mrs. R. H.

Pentz) both residents of St. George, Staten Island, and several grandchildren. A son, Roger Frederick, died in early manhood.

Arthur Hollick was a man of broad interests, keeping in touch with the best in English poetry and prose; an enthusiastic devotee of golf and bowling; a productive scientist of wide range; an excellent lecturer; a man of a sensitive responsive nature; a man with the instincts of a gentleman and, withal, a man whom his associates will miss.

List of scientific publications by Arthur Hollick[1]

[With N. L. Britton.] The flora of Richmond County, New York. 1–36. Staten Island. 1879.

A few notes on the abnormal absence of color in plants. Bull. Torrey Club **6**: 293–296. Mr 1879.

Notes on the flora of the Lake Superior copper region. Bull. Torrey Club **6**: 349. O 1879.

[With N. L. Britton.] Flora of Richmond County, N. Y. Additions and new localities, 1879. Bull. Torrey Club **7**: 11, 12. Ja 1880. [Also reprinted.]

Relations between geological formations and the distribution of plants. Bull. Torrey Club **7**: 14, 15. F 1880.

Abnormal growths in ferns. Bull. Torrey Club **9**: 129. O 1882. [illust.]

[With N. L. Britton.] Flora of Richmond County, N. Y. Additions and new localities, 1880–1882. Bull. Torrey Club **9**: 149–151. D 1882. [Also reprinted.]

Notice in regard to fossil leaves found at Tottenville, Staten Island. Proc. Nat. Sci. Assoc. Staten Island [**1**: 3]. 8 D 1883.

Recent discoveries of Indian implements at Tottenville. Proc. Nat. Sci. Assoc. Staten Island [**1**: 8]. 10 My 1884.

Notice in regard to recent discoveries in the shell mounds near Tottenville and Kreischerville, Staten Island. Proc. Nat. Sci. Assoc. Staten Island [**1**: 12]. 11 O 1884.

Note on the peat bogs in the vicinity of Richmond, Staten Island. Proc. Nat. Sci. Assoc. Staten Island [**1**: 18]. 14 F 1885.

[With N. L. Britton.] Flora of Richmond County, N. Y. Additions and new localities, 1883–1884. Bull. Torrey Club **12**: 38–40. Ap 1885. [Also reprinted.]

Notes in connection with the third appendix to the flora of Richmond County, N. Y. Proc. Nat. Sci. Assoc. Staten Island [**1**: 22]. 13 Je 1885.

On some peculiar leafy berries of *Mitchella repens* L. Proc. Nat. Sci. Assoc. Staten Island [**1**: 25]. 10 O 1885.

Preliminary list of the birds known to breed on Staten Island. Proc. Nat. Sci. Assoc. Staten Island [**1**: 28]. Extra no. 4. D 1885.

Notice in regard to fossil vegetable remains from the Kreischerville clays. Proc. Nat. Sci. Assoc. Staten Island [**1**: 31]. 13 F 1886.

[With N. L. Britton.] Flora of Richmond County, N. Y. Additions and new localities, 1885. Bull. Torrey Club **13**: 83, 84. My 1886. [Also reprinted.]

Remarks upon Indian implements and deer bones from the shell heaps at Morgans, N. J. Proc. Nat. Sci. Assoc. Staten Island [**1**: 34]. 8 My 1886.

[1] In the following bibliography, Dr. Hollick's early reports as a sanitary engineer, his numerous reviews, and his contributions to newspapers have, for the most part, been omitted.

Memorandum in regard to bird destruction. Proc. Nat. Sci. Assoc. Staten Island [1: 36]. Extra no. 5. Jl 1886.

Remarks in connection with the sixth annual meeting of the Natural Science Association of Staten Island. Proc. Nat. Sci. Assoc. Staten Island [1: 42]. 13 N 1886.

[Glaciation on Staten Island] Proc. Nat. Sci. Assoc. Staten Island. [1: 45]. 11 D 1886.

[Botanical portion of the chapter on natural history.] Preston's History of Richmond County, 20–30. 1887.

Size and probable age of a number of Staten Island trees. Proc. Nat. Sci. Assoc. Staten Island [1: 47]. 12 F 1887.

[With N. L. Britton.] *Cerastium arvense* L., and its North American varieties. Bull. Torrey Club **14:** 45–51. *pl. 63–65.* Mr 1887. [Also reprinted.]

Notes on Indian pottery. Proc. Nat. Sci. Assoc. Staten Island. [1: 59]. 12 N 1887.

[Remarks upon Indian hammerstones.] Trans. N. Y. Acad. Sci. **7:** 136, 137. 1888.

On a peculiar *Heleocharis* found in a spring at West New Brighton. Proc. Nat. Sci. Assoc. Staten Island [1: 63]. 10 Mr 1888.

A recent discovery of hybrid oaks on Staten Island. Bull. Torrey Club **15:** 303–309. *pl. 83–85.* D 1888. [Also reprinted.]

[Triassic outcrop at Mariners' Harbor, Staten Island, N. Y.] Proc. Nat. Sci. Assoc. Staten Island **2:** 9, 10. 11 Ap 1889; Amer. Nat. **23:** 1033–1034. 1889.

[With N. L. Britton.] Flora of Richmond County, N. Y. Additions and new localities, 1886–1889. Bull. Torrey Club **16:** 132–134. My 1889. [Also reprinted].

Record of the dates of flowering of *Anemone Hepatica* L. Proc. Nat. Sci. Assoc. Staten Island [2: 44]. 13 Mr 1890.

[Remarks on screw-like fossils.] Trans. N. Y. Acad. Sci. **13:** 118, 119. 1893.

Notes on the autumn flora of southeastern Virginia. Mem. Torrey Club **2:** 54–56. D 1890.

A memorial of the late Dr. John I. Northrop. Trans. N. Y. Acad. Sci. **11:** 9–12. 1891.

Notes on additions to the flora of Staten Island. Proc. Nat. Sci. Assoc. Staten Island [2: 71]. 10 Ja 1891.

[With N. L. Britton.] Flora of Richmond County, N. Y. Additions and new localities, 1890. Bull. Torrey Club **18:** 213, 214. Jl 1891. [Also reprinted.]

Biographical notice of Dr. N. L. Britton. Staten Islander. 21 Jl 1891.

A trip to Montauk Point, Long Island. Bull. Torrey Club **18:** 255, 256. Au 1891.

Botany at the A. A. A. S. Bull. Torrey Club **18:** 273–277. S 1891.

The paleontology of the Cretaceous formation on Staten Island. Trans. New York Acad. Sci. **11:** 96–104. *pl. 1–4.* 1892.

Additions to the palaeobotany of the Cretaceous formation on Staten Island. Trans. New York Acad. Sci. **12:** 28–39. *pl. 1–4.* 1892.

[Notes on the paleontology of the Cretaceous formation in Staten Island.] Proc. Nat. Sci. Assoc. Staten Island [3: 7, 8]. 9 Ja 1892.

Botanical notes. Proc. Nat. Sci. Assoc. Staten Island [3: 14]. 14 My 1892.

Palaeobotany of the yellow gravel at Bridgeton, N. J. Bull. Torrey Club **19:** 330–333. N 1892. [Also reprinted.]

Additions to the Cretaceous flora of Staten Island. Proc. Nat. Sci. Assoc. Staten Island [3: 23]. 12 N 1892.

[Notes on Staten Island clays collected for the World's Fair.] Proc. Nat. Sci. Assoc. Staten Island [3: 26, 27]. 17 D 1892.

Preliminary contribution to our knowledge of the Cretaceous formation on Long Island and eastward. Trans. New York Acad. Sci. **12:** 222–237. *pl. 5–7.* 1893.

Observations on the geology and botany of Martha's Vineyard. Trans. New York Acad. Sci. **13:** 8–22. 1893.

Notes on the geology of the new railroad cut at Arrochar [Staten Island, N. Y.]. Proc. Nat. Sci. Assoc. Staten Island [**3:** 45–47]. 1893.

[Triassic sandstone with fossils in drift material on Staten Island.] Proc. Nat. Sci. Assoc. Staten Island [**3:** 50]. 1893.

Some further notes upon *Serenopsis Kempii.* Bull. Torrey Club **20:** 334. 1893.

Plant distribution as a factor in the interpretation of geological phenomena, with special reference to Long Island and vicinity. Trans. N. Y. Acad. Sci. **12:** 189–202. 1893.

A recent find of drift fossils at Prince's Bay [Staten Island, N. Y.]. Proc. Nat. Sci. Assoc. Staten Island **4:** 2. 11 N 1893.

Mineralogical notes [Staten Island, N. Y.]. Proc. Nat. Sci. Assoc. Staten Island **4:** 5, 7. 9 D 1893.

[With J. F. Kemp.] The granite at Mounts Adam and Eve, Warwick, Orange County, New York, and its contact phenomena. Ann. N. Y. Acad. Sci. **7:** 638–650. *pl. 2, 3.* 1894.

Some further notes on the geology of the north shore of Long Island. Trans. New York Acad. Sci. **13:** 122–130. 1894.

Additions to the paleobotany of the Cretaceous formation on Long Island. Bull. Torrey Club **21:** 49–65. *pl. 174–180.* 1894.

Fossil Salvinias, including description of a new species. Bull. Torrey Club **21:** 253–257. *pl. 205.* 1894.

A new fossil *Nelumbo* from the Laramie group at Florence, Colo. Bull. Torrey Club **21:** 307–310. 1894. [illust.]

Wing-like appendages in the petioles of *Liriophyllum populoides* Lesq. and *Liriodendron alatum* Newb., with description of the latter. Bull. Torrey Club **21:** 467–471. *pl. 220, 221.* 1894.

Recent investigations in the Cretaceous formation on Long Island, N. Y. Proc. Am. Assoc. Adv. Sci. **42:** 175. 1894. [Abstract.]

Notes on the northward extension of the yellow gravel in New Jersey, Staten Island, Long Island, and eastward. Proc. Am. Assoc. Adv. Sci. **42:** 175, 176. 1894. [Abstract.]

Dislocations in certain portions of the Atlantic Coastal Plain strata and their probable causes. Trans. N. Y. Acad. Sci. **14:** 8–20, *f. 1–5.* 15 O 1894.

Plant remains in limonite from the moraine at Clifton, Staten Island, N. Y. and their significance. Proc. Nat. Sci. Assoc. Staten Island **4:** 37, 38. 13 O 1894.

Descriptions of new leaves from the Cretaceous (Dakota group) of Kansas. Bull. Torrey Club **22:** 225–228, *pl. 236, 237.* 1895.

A new fossil *Liriodendron* from the Laramie at Walsenberg, Colo., and its significance. Proc. Am. Assoc. Adv. Sci. **43:** 225. Mr 1895. [Abstract.]

Further discovery of drift fossils at Prince's Bay [Staten Island, N. Y.]. Proc. Nat. Sci. Assoc. Staten Island **5:** 3. 9 N 1895.

Recent discovery of the occurrence of marine Cretaceous strata on Long Island. Amer. Geol. **16:** 248. 1895; Science, II. **2:** 400. 1895; Proc. Am. Assoc. Adv. Sci. **44:** 133–135. 1896.

Geological notes: Long Island and Nantucket. Trans. New York Acad. Sci. **15:** 3–10. 1896.

The tulip tree and its ancestors. Proc. Nat. Sci. Assoc. Staten Island **5:** 80. 9 My 1896.

Geological notes: Long Island and Block Island. Trans. New York Acad. Sci. **16:** 9–18. 1896.

New species of leguminous pods from the yellow gravel at Bridgeton, N. J. Bull. Torrey Club **23:** 46–49. *pl. 258, 259.* 1896.

Appendages to the petioles of Liriodendra. Bull. Torrey Club **23:** 249, 250. *pl. 269, 270.* 1896.

Recent additions to the Cretaceous fossil flora of Staten Island, [N. Y.]. Proc. Nat. Sci. Assoc. Staten Island **6:** 2. 1896.

Iron ore from the vicinity of New Springville [Staten Island, N. Y.]. Proc. Nat. Sci. Assoc. Staten Island **5:** 12. 11 Ja 1896.

The Cretaceous clay marl exposure at Cliffwood, N. J. Trans. New York Acad. Sci. **16:** 124–136. *pl. 11–14+f. 1, 2.* 1897.

A new fossil grass from Staten Island. Bull. Torrey Club **24:** 122–124. *pl. 298.* 1897.

A new fossil monocotyledon from the yellow gravel at Bridgeton, N. J. Bull. Torrey Club **24:** 329–331. *pl. 311–313.* 1897.

Affinities of *Caulinites* Ad. Brong. Bull. Torrey Club **24:** 582, 583. *pl. 320.* 1897.

A new investigation of man's antiquity at Trenton, [N. J.]. Science II. **6:** 675–682. 1897.

[The geological section at Cliffwood, N. J.]. Science, II. **5:** 239. 1897. [Abstract.]

The old field pine in New Jersey. Plant World **1:** 24, 25. N 1897.

Further notes on Block Island, (N. Y.). Amer. Geol. **22:** 200, 201. 1898.

Exposure of Cretaceous material on Fingerboard Road [Staten Island, N. Y.]. Proc. Nat. Sci. Assoc. Staten Island **6:** 55, 56. 1898.

Notes on glacial phenomena of Staten Island, N. Y. Ann. N. Y. Acad. Sci. **11:** 482. 1898. Science, II. **8:** 840. 1898. [Abstract.]

The age of the Amboy Clay series as indicated by its flora. Proc. Am. Assoc. Adv. Sci. **47:** 292, 293. 1898. [Abstract.] Amer. Geol. **22:** 255, 256. 1898. Science, II. **8:** 467, 468. 1898.

Notes on Block Island. Ann. New York Acad. Sci. **11:** 55–72. *pl. 2–9.* 1898.

Additions to the paleobotany of the Cretaceous formation on Staten Island, No. II. Ann. New York Acad. Sci. **11:** 415–430. *pl. 36–38.* 1898.

The relation between forestry and geology in New Jersey. Second report of progress. Ann. Rep. State Geologist of New Jersey for **1898:** 28, 29. 1899.

Some features of the drift on Staten Island, N. Y. Amer. Geol. **22:** 247. 1898; Science, II. **8:** 463. 1898; Ann. N. Y. Acad. Sci. **12:** 91–102. 7 Jl 1899; Bull. Geol. Soc. Am. **10:** 2–4. Ja 1899.

Proceedings of Section E—Geography and Geology, American Association for the Advancement of Science. Columbus, Ohio, Meeting, 1899. Science II. **10:** 487–491. 1899.

[Appendix to Mrs. N. L. Britton's "A new tertiary fossil moss."] Bull. Torrey Club **26:** 80, 81. F 1899. [illust.]

An example of isostasy. Proc. Nat. Sci. Assoc. Staten Island **7:** 9, 10. 11 F 1899.

Notes on deep wells at Prince's Bay and Huguenot. Proc. Nat. Sci. Assoc. Staten Island **7:** 19. 10 Je 1899.

The relation between forestry and geology in New Jersey. Am. Nat. **33:** 1–14. *map.* Ja 1899; 109–116. F 1899.

Notes on the geology and botany of the Fox Hills Golf Links. Proc. Nat. Sci. Assoc. Staten Island. **7:** 20–22. 9 S 1899.

A quaternary lake deposit in the Moravian Cemetery. Proc. Nat. Sci. Assoc. Staten Island **7:** 24, 25. 14 O 1899.

The relation between forestry and geology in New Jersey. [Final Rep.] Ann. Rep. State Geologist of New Jersey for 1899. Rep. on Forests. 175–201. 1900. [illust.]

A report on a collection of fossil plants from northwestern Louisiana. Geol. Surv. Louisiana, Rep. for 1899, Special Rep. No. **5:** 276–288. *pl. 32–48.* 1900.

Geological notes. Proc. Nat. Sci. Assoc. Staten Island **7:** 30–32. 3 Ja 1900.

Further notes on the quaternary lake deposit in Moravian Cemetery. Proc. Nat. Sci. Assoc. Staten Island **7:** 33, 34. 10 F 1900.

Drift and kame deposits on the line of the South Side Boulevard. Proc. Nat. Sci. Assoc. Staten Island **7:** 37. 14 Ap 1900.

An example of deductive reasoning. Plant World **3:** 184, 185. D 1900.

Some recent finds of fossiliferous drift bowlders. Proc. Nat. Sci. Assoc. Staten Island **7:** 1, 2. 8 D 1900.

Discovery of a mastodon's tooth and the remains of a boreal vegetation in a swamp on Staten Island, N. Y. Ann. New York Acad. Sci. **14:** 67, 68. 1901.

Plantae [fossil plants]. Maryland Geol. Surv., Eocene, systematic paleontology: 258, 259. *pl. 64+f. 11–12b.* 1901.

A reconnaissance of the Elizabeth Islands. Ann. N. Y. Acad. Sci. **13:** 387–418. *pl. 8–15.* 14 Ja 1901.

Notes on some Staten Island birds. Proc. Nat. Sci. Assoc. Staten Island **7:** 12, 13. 13 Ap 1901.

Two Staten Island sponges. Proc. Nat. Sci. Assoc. Staten Island **8:** 21. 12 O 1901.

Grape leaves blighted by acid fumes. Proc. Nat. Sci. Assoc. Staten Island **8:** 21, 22. 12 O 1901.

List of fungi, collected at Tottenville, Oct. 4th, 1890. Proc. Nat. Sci. Assoc. Staten Island **8:** 25. 14 D 1901.

Fossil ferns from the Laramie group of Colorado. Torreya **2:** 145–148. *pl. 4, 5.* 1902.

Geological and botanical notes: Cape Cod and Chappaquidick Island, Mass. Bull. New York Bot. Gard. **2:** 381–407. *pl. 40, 41.* 1902.

Paleobotany at the Garden. Jour. N. Y. Bot. Gard. **3:** 27–29. F 1902.

Notes on the ice storm of February 21st. Proc. Nat. Sci. Assoc. Staten Island **8:** 33, 34. 8 Mr 1902.

The endowment of research. Science II. **15:** 472. 21 Mr 1902.

Notes on our common stemless blue violets. Proc. Nat. Sci. Assoc. Staten Island **8:** 39. 19 My 1902.

Notes on recent exposures in the soapstone rock. Proc. Nat. Sci. Assoc. Staten Island **8:** 41, 42. 4 O 1902.

New York City Folio No. 83. Geologic Atlas of the United States. U. S. Geol. Surv. 10, 11. 1902. [1903].

Paleobotany. The New International Encyclopaedia **13:** 590–594. 1903.

Field work during 1901 in the Cretaceous beds of Long Island. 55th Ann. Rep. N. Y. State Mus. **1901**: r48–r51. 1903.

A fossil petal and a fossil fruit from the Cretaceous (Dakota group) of Kansas. Bull. Torrey Club **30**: 102–105. *f. A, B 1–6*. F 1903.

Fossil plants from Kansas. Jour. N. Y. Bot. Gard. **4**: 66–68. *f. 8*. Ap 1903.

Some recently discovered facts in regard to Silver Lake [Staten Island, N. Y.]. Proc. Nat. Sci. Assoc. Staten Island **9**: 11–13. 1904.

A canoe trip down the Yukon River from Dawson to Anvik. Ann. N. Y. Acad. Sci. **16**: 333–335. 1905; Science II. **19**: 859. 1904; Amer. Geol. **33**: 339. 1904.

Plantae [fossil plants]. Maryland Geol. Surv., Miocene, systematic paleontology: 483–486. *f. 1*. 1904.

Paleobotany, or fossil botany. Encyclopaedia Americana **11**: n. p. 1904.

Botanical notes. Proc. Nat. Sci. Assoc. Staten Island **9**: 25, 26. 15 O 1904.

Geological notes. Proc. Nat. Sci. Assoc. Staten Island **9**: 25. 15 O 1904.

A recent discovery of amber and other fossil plant remains at Kreischerville. Proc. Nat. Sci. Assoc. Staten Island **9**: 31, 32. 12 N 1904.

A remarkable sewer obstruction. Proc. Nat. Sci. Assoc. Staten Island **9**: 33. 17 D 1904.

Additions to the paleobotany of the Cretaceous formation on Long Island. No. II. Bull. New York Bot. Gard. **3**: 403–418. *pl. 70–79*. 1905.

The occurrence and origin of amber in the eastern United States. Amer. Nat. **39**: 137–145. *pl. 1–3*. 1905.

Additional notes on the occurrence of amber at Kreischerville. Proc. Nat. Sci. Assoc. Staten Island **9**: 35, 36. Ja 1905.

A recent discovery of amber on Staten Island. Jour. N. Y. Bot. Gard. **6**: 45–48. *f. 14, 15*. Mr 1905.

Staten Island's first resident naturalist. Proc. Nat. Sci. Assoc. Staten Island **9**: 43–45. 15 Ap 1905.

The preservation of plants by geologic processes. Jour. N. Y. Bot. Gard. **6**: 115–118. *f. 28–30*. Jl 1905.

Palaeobotanical notes. Jour. N. Y. Bot. Gard. **6**: 148, 149. S 1905.

[With E. C. Jeffrey.] Affinities of certain Cretaceous plant remains commonly referred to the genera *Dammara* and *Brachyphyllum*. Am. Nat. **40**: 189–216. *pl. 1–5*. 1906.

[Fossil plants.] Maryland Geol. Surv., Pliocene and Pleistocene: 217–237, 273–281. *pl. 67–75*. 1906.

The Cretaceous flora of southern New York and New England. Monog. U. S. Geol. Surv. **50**: 1–219. *pl. 1–40*. 1906.

Studies of extinct plants of the Atlantic Coast. Jour. N. Y. Bot. Gard. **7**: 168, 169. 1906.

The Pliocene and Pleistocene deposits of Maryland; the interpretation of the paleontological criteria; the Pleistocene flora. Maryland Geol. Surv. Pliocene and Pleistocene: 148, 149. 1906.

A newly discovered outcrop of Triassic rock on Staten Island [N. Y.]. Proc. Staten Island Assoc. Arts and Sci. **1**: 16, 17. 1906.

Origin of the amber found on Staten Island. Jour. N. Y. Bot. Gard. **7**: 11, 12. Ja 1906.

A soapstone drift bowlder containing magnetite. Proc. Staten Island Assoc. Arts and Sci. **1**: 31, 32. Mr 1906.

The type of *Zamites montanensis* Font. Jour. N. Y. Bot. Gard. **7**: 115, 116. Ap 1906.

A fossil forest fire. Proc. Staten Island Assoc. Arts and Sci. **1**: 21–23. 9 Jl 1906.

Insect borings in Cretaceous lignite from Kreischerville. Proc. Staten Island Assoc. Arts. and Sci. **1**: 23, 24. 9 Jl 1906.

An addition to the flora of Block Island. Torreya **6**: 190. 27 S 1906.

[With E. G. Britton.] American fossil mosses, with description of a new species from Florissant, Colorado. Bull. Torrey Club **34**: 139–142. *pl. 9*. 1907.

Description of a new Tertiary fossil flower from Florissant, Colorado. Torreya **7**: 182–184. *f. 1, 2*. 1907.

Address as delegate from the Staten Island Assoc. Arts and Sci. to the celebration by the New York Academy of Sciences of the 200th anniversary of the birth of Linnaeus, May 23, 1907. Proc. Staten Island Assoc. Arts and Sci. **1**: 127, 128. My 1907.

A collection of fossil gums. Jour. N. Y. Bot. Gard. **8**: 163–165. Jl 1907.

Discovery of lignitic and bituminous coal at Kreischerville. Proc. Staten Island Assoc. Arts and Sci. **2**: 13. 17 O 1908.

Drift boulders from the shore at Tottenville. Proc. Staten Island Assoc. Arts and Sci. **2**: 9. 17 O 1908.

Chemical analysis of Cretaceous amber from Krieschervilie. Proc. Staten Island Assoc. Arts and Sci. **2**: 34. 17 O 1908.

The museum collection of fossil plants. Jour. N. Y. Bot. Gard. **9**: 214–226. D 1908.

A new genus of fossil Fagaceae from Colorado. Torreya **9**: 1–3. *f. 1, 2*. 1909.

[With E. C. Jeffrey.] Studies of Cretaceous coniferous remains from Kreischerville, New York. Mem. New York Bot. Gard. **3**: i–xiii+1–138. *pl. 1–29*. 1909.

A new fossil polypore. Mycologia **2**: 93, 94. *f. 1, 2*. 1910.

Notes in connection with specimens recently obtained from the serpentines of Staten Island [N. Y.]. Ann. N. Y. Acad. Sci. **19**: 315–317. 1910. [Abstract.]

The fossil flora of New York and vicinity. Jour. N. Y. Bot. Gard. **11**: 15–19. Ja 1910.

A new fossil fucoid. Bull. Torrey Club **37**: 305–307. *pl. 33*. 21 Jl 1910.

The chestnut disease on Staten Island. Proc. Staten Island Assoc. Arts and Sci. **2**: 125–127. 18 Au 1910.

Geological notes in connection with a recent lawsuit against the City. Proc. Staten Island Assoc. Arts and Sci. **2**: 144–147. 18 Au 1910.

Recently introduced grasses and sedges. Proc. Staten Island Assoc. Arts and Sci. **2**: 189. 16 S 1910.

A maple tree fungus. Proc. Staten Island Assoc. Arts and Sci. **2**: 190–192. 16 S 1910.

Results of a preliminary study of the so-called Kenai flora of Alaska. Am. Jour. Sci. **31**: 327–330. Ap 1911.

Notes on specimens recently collected in the serpentine area of Staten Island. Proc. Staten Island Assoc. Arts and Sci. **3**: 31–33. 28 Ap 1911.

Notes on introduced plants collected near Arlington, Staten Island. Proc. Staten Island Assoc. Arts and Sci. **3**: 62–65. 2 My 1911.

The paleobotanical collections of The New York Botanical Garden. Proc. Am. Assoc. Mus. **4**: 43–52. My 1911.

A rare and little-known publication. Torreya **11**: 150–152. 19 Jl 1911.

Stangeria or *Stangera* and *Stangerites* or *Strangerites*? Two questions of nomenclature. Torreya **11**: 174, 175. 14 Au 1911.

Changes and inconsistencies in the spelling of local place-names by the United States Geological Survey. Proc. Staten Island Assoc. Arts and Sci. **3**: 109–112. F 1912.

Modern aspects of paleobotany—II. Relation of paleobotany to botany. 3. Ecology. Am. Nat. **46**: 239–243. Ap 1912.

Some features of the Dismal Swamp of Virginia. Jour. N. Y. Bot. Gard. **13**: 53–56. *pl. 91, 92.* Ap 1912.

Pot-holes in The New York Botanical Garden. Jour. N. Y. Bot. Gard. **14**: 157–160. *pl. 122–124.* O 1913.

Additions to the paleobotany of the Cretaceous formation on Long Island. No. III. Bull. N. Y. Bot. Gard. **8**: 154–170. *pl. 162–170.* N 1912.

Preliminary correlation of the Cretaceous and Tertiary floras of Alaska. Bull. Geol. Soc. Am. **24**: 115. Mr 1913. [Abstract.]

Lester Frank Ward. Science **38**: 75–77. 18 Jl 1913.

Former climatic conditions in Alaska, as indicated by the Cretaceous and Tertiary floras. Jour. N. Y. Bot. Gard. **14**: 210–213. D 1913.

A preliminary report by Mr. Arthur Hollock [Hollick] of the New York Botanical Garden upon the plants of the Pleistocene deposits. Canada Geol. Survey, Dept. Mines, Summary Report. **1913**: 133–135. 1914.

Fossil wood from the petrified forest of Arizona. Jour. N. Y. Bot. Gard. **15**: 181, 182. S 1914.

A conspicuous Staten Island boulder trail. Proc. Staten Island Assoc. Arts and Sci. **5**: 8, 9. 1915.

[With E. G. Britton.] A new American fossil moss. Bull. Torrey Club **42**: 9, 10. *f. 1, 2.* 29 Ja 1915.

Report of the honorary curator of the collection of fossil plants [for 1914]. Bull. N. Y. Bot. Gard. **9**: 38, 39. 31 Mr 1915.

Union of an oak and a beech. Proc. Staten Island Assoc. Arts and Sci. **5**: 11, 12. *pl. 1+f. 2.* 24 Ap 1915.

A new species of *Ficus* and its climatic significance. Jour. N. Y. Bot. Gard. **16**: 43–47. *pl. 152, 153.* 10 Ap 1915.

Note on a seedling *Quercus heterophylla* Michx. Proc. Staten Island Assoc. Arts and Sci. **5**: 141, 142. 1916.

Report of the honorary curator of the collection of fossil plants [for 1915]. Bull. N. Y. Bot. Gard. **9**: 128. 20 Mr 1916.

Some botanical and geological features of the Silver Lake basin. Proc. Staten Island Assoc. Arts and Sci. **5**: 60–65. *pl. 2–5.* 10 Ap 1916.

A quaint old work on sea weeds. Proc. Staten Island Assoc. Arts and Sci. 85–91. 10 Ap 1916.

A rose fungus found on Staten Island. Proc. Staten Island Assoc. Arts and Sci. **5**: 139. 10 Ap 1916.

Note on bayberry wax (*Myrica caroliniana* Mill.) Proc. Staten Island Assoc. Arts and Sci. **5**: 110, 111. 10 Ap 1916.

A fossil fern monstrosity. Mem. N. Y. Bot. Gard. **6**: 473, 474. *pl. 31, 32.* 31 Au 1916.

Report of the honorary curator of the collection of fossil plants [for 1916]. Bull. N. Y. Bot. Gard. **9**: 334, 335. 10 Ap 1917.

Housman's Cave. Proc. Staten Island Assoc. Arts and Sci. **6**: 69–71. 9 My 1917. [illust.]

Sanderson Smith. Proc. Staten Island Assoc. Arts and Sci. **6**: 141–143. *portrait.* 30 N 1917.

Additional notes on the botany of Silver Lake basin. Proc. Staten Island Assoc. Arts and Sci. **6**: 67, 68. *f. 1, 2.* 9 My 1917.

Some botanical problems that paleobotany has helped to solve. Brooklyn Bot. Gard. Mem. **1**: 187–190. 1918.

Aster Novae-angliae. Addisonia **3**: 3. *pl. 82.* 30 Mr 1918.

Report of the honorary curator of fossil plants [for 1917]. Bull. N. Y. Bot. Gard. **9**: 463. 30 Ap 1918.

Torrey Botanical Club reminiscences. Mem. Torrey Club **17**: 29, 30. 10 Je 1918.

Report of the honorary curator of the collection of fossil plants [for 1918]. Bull. N. Y. Bot. Gard. **10**: 54, 55. 12 My 1919.

Training of museum workers. Museum Work **1**: 246, 247. My 1919.

The story of the Bartram oak. Sci. Am. **121**: 422, 429, 430, 432. 25 O 1919. [illust.]

A graphical representation of geologic time. Sci. Am. **122**: 27. 10 Ja 1920. [illust.]

Report of the honorary curator of fossil plants [for 1919]. Bull. N. Y. Bot. Gard. **10**: 272, 273. 30 Je 1920.

Bird of paradise plumage. Proc. Staten Island Assoc. Arts and Sci. **7**: 1–4. 21 Je 1920.

Quercus heterophylla in the Clove Valley. Proc. Staten Island Assoc. Arts and Sci. **7**: 32–34. *pl. 4.* 21 Je 1920.

Note on an albino specimen of purple *Gerardia.* Proc. Staten Island Assoc. Arts and Sci. **7**: 58. 21 Je 1920.

Notes on botanical specimens collected at Arlington, Staten Island. Proc. Staten Island Assoc. Arts and Sci. **7**: 58. 21 Je 1920.

The museum of fossil botany. Bull. N. Y. Bot. Gard. **10**: 120–124. *pl. 205.* 24 Je 1920.

Loco weeds. Nat. Hist. **21**: 85–91. [Issue for Ja] F 1921. [illust.]

Report of the honorary curator of fossil plants [for 1920]. Bull. N. Y. Bot. Gard. **10**: 359. 10 S 1921.

Paulownia in winter. Jour. N. Y. Bot. Gard. **23**: 1–3. *pl. 267, 268.* Ja 1922.

Local flora notes—Staten Island. Torreya **22**: 1–3. Ja & F 1922.

Report of the paleobotanist [for 1921]. Bull. N. Y. Bot. Gard. **12**: 63, 64. 6 Jl 1922.

Note on *Globiformes graveolens* from Staten Island. A fungus new to the local flora. Proc. Staten Island Inst. Arts and Sci. **1**: 66, 67. 29 Au 1922.

Note on *Tussilago Farfara* L. and its recent distribution on Staten Island. Proc. Staten Island Inst. Arts and Sci. **1**: 67. 29 Au 1922.

Alnus rugosa. Addisonia **7**: 25, 30. *pl. 237.* 25 S 1922.

Report of the paleobotanist [for 1922]. Bull. N. Y. Bot. Gard. **12**: 142–144. 7 Je 1923.

The taxonomic and morphologic status of *Ophioglossum Alleni* Lesq. Bull. Torrey Club **50**: 207–213. *pl. 10–12.* 6 Jl 1923.

Cycads, living and extinct. Jour. N. Y. Bot. Gard. **24**: 135–140. Jl 1923. [illust.]

Menispermum canadense. Addisonia **8**: 41, 42. *pl. 277.* S 1923.

Erect silky leather flower on Staten Island. Proc. Staten Island Inst. Arts and Sci. **1**: 120–122. 13 O 1923.

Syndesmon thalictroides. Addisonia **8**: 55. *pl. 284*. D 1923.

[With E. W. Berry.] A late tertiary flora from Bahia, Brazil. The Johns Hopkins Univ. Studies in Geology **5**: 1–136. *pl. 1–13*. 1924.

The ancestral history of some existing plants. Jour. N. Y. Bot. Gard. **25**: 14, 15. Ja 1924. [Abstract of lecture.]

The Joseph Leidy commemorative meeting. Jour. N. Y. Bot. Gard. **25**: 18, 19. Ja 1924. [unsigned.]

A review of the fossil flora of the West Indies. Jour. Washington Acad. Sci. **14**: 58. 19 Ja 1924. [Abstract of paper.]

[Note on concretions.] Jour. N. Y. Bot. Gard. **25**: 23. Ja 1924.

When a tropical vegetation existed in Alaska. Jour. N. Y. Bot. Gard. **25**: 33–35. F 1924. [Abstract of lecture.]

Report of the paleobotanist [for 1923]. Bull. N. Y. Bot. Gard. **12**: 218–220. 28 My 1924.

Swamps, ancient and modern. Jour. N. Y. Bot. Gard. **25**: 145–147. My 1924. [Abstract of lecture.]

A review of the fossil flora of the West Indies, with descriptions of new species. Bull. N. Y. Bot. Gard. **12**: 259–323. *pl. 1–15*+*f. 1*. 13 S 1924.

Pinus rigida. Addisonia **9**: 45, 46. *pl. 311*. 15 N 1924.

The Hudson River valley before the advent of man. Jour. N. Y. Bot. Gard. **25**: 296–299. N 1924. [Abstract of lecture.]

The Bartram oak. Jour. N. Y. Bot. Gard. **25**: 305–313. *f. 1–4*. "D 1924" [20 Ja 1925.]

An interglacial flora from Kootenay Valley in British Columbia. Jour. N. Y. Bot. Gard. **26**: 13, 14. Ja 1925. [Under Conference Notes for December.]

The geology of The New York Botanical Garden. Jour. N. Y. Bot. Gard. **26**: 3–6. Ja 1925. [Abstract of lecture.]

A new fossil species of *Hydrangea*. Bull. Torrey Club. **52**: 21, 22. *pl. 2*. Ja 1925. [Abstract in Rev. Géologie **6**: 357.]

Some plants concerned in the formation of coal. Jour. N. Y. Bot. Gard. **26**: 54–57. Mr 1925. [Abstract of lecture.]

[Author's abstract of] Arthur Hollick's A review of the fossil flora of the West Indies, with descriptions of new species. Revue de Géologie **5**: 838. "D 1924." [Issued Mr 1925.]

Report of the paleobotanist [for the year 1924]. Bull. N. Y. Bot. Gard. **13**: 40–42. 30 Jl 1925.

The dismal swamp of Virginia. Jour. N. Y. Bot. Gard. **26**: 227–230. O 1925. [Abstract of lecture.]

The origin and history of soils. Jour. N. Y. Bot. Gard. **27**: 29–33. F 1926. [Abstract of lecture.]

Report on a tree trunk and associated lignitic débris excavated in Manhattan Island. Amer. Mus. Novitates **213**: 1–6. *f. 1, 2*. 6 My 1926.

Paleobotanical exploration in Porto Rico. Jour. N. Y. Bot. Gard. **27**: 102–104. My 1926.

Report of the paleobotanist [for 1925]. Bull. N. Y. Bot. Gard. **13**: 134, 135. 3 Je 1926.

A historical review of the study of fossil plants. Jour. N. Y. Bot. Gard. **27:** 177–180. Au 1926. [Abstract of lecture.]

Fossil walnuts and lignite from Porto Rico. Jour. N. Y. Bot. Gard. **27:** 223–227. *f. 1.* O 1926.

Records of glaciation in The New York Botanical Garden. Jour. N. Y. Bot. Gard. **27:** 269–278. *f. 1–7.* D 1926.

The flora of the Saint Eugene silts, Kootenay Valley, British Columbia. Mem. N. Y. Bot. Gard. **7:** 389–464. *pl. 29–47*+*f. 1.* Mr 1927.

Quercus serrata. Addisonia **12:** 25. *pl. 397.* 30 Je 1927.

Report of the paleobotanist [for 1926]. Bull. N. Y. Bot. Gard. **13:** 217, 218. 8 Je 1927.

Fossil plants of New York City and vicinity. Jour. N. Y. Bot. Gard. **28:** 163–166. Jl 1927.

Some geological features of The New York Botanical Garden. Jour. N. Y. Bot. Gard. **28:** 197–200. Au 1927.

Pleistocene plant remains from Cuba and A new method of illustrating identifications of fossil leaf remains. Jour. N. Y. Bot. Gard. **29:** 115, 116. My 1928. [In Conference Notes for April.]

Report of the paleobotanist [for 1927]. Bull. N. Y. Bot. Gard. **13:** 309–311. 31 My 1928.

A white oak killed by lightning. Jour. N. Y. Bot. Gard. **29:** 179–182. *f. 7.* Jl 1928. [Abstracts of this appeared in various newspapers.]

Isotria verticillata on Staten Island, New York. Torreya **28:** 69, 70. *pl. A, B.* Jl-Au 1928.

Paleobotany of Porto Rico. N. Y. Acad. Sci. Scientific Survey Porto Rico and Virgin Islands. **7:** 175–393. *pl. 51–88.* 31 O 1928.

The story of the redwoods. Jour. N. Y. Bot. Gard. **29:** 281, 282. N 1928. [Abstract of lecture.]

New species of fossil plants from the Tertiary shales near De Beque, Colorado. Bull. Torrey Club **56:** 93–96. *pl. 2.* "F 1929" [26 Mr 1929].

Report of the paleobotanist [for 1928]. Bull. N. Y. Bot. Gard. **13:** 382–384. 31 My 1929.

Botany in relation to geology. Jour. N. Y. Bot. Gard. **30:** 162–166. Jl 1929. [Abstract of lecture.]

The petrified forests of Arizona. Jour. N. Y. Bot. Gard. **31:** 14–18. Ja 1930. [Abstract of lecture.]

[Notes on recent studies of Tertiary cycads.] Jour. N. Y. Bot. Gard. **31:** 19, 20. Ja 1930. [Under Conference Notes for November.]

Report of the paleobotanist [for 1929]. Bull. N. Y. Bot. Gard. **14:** 203, 204. 3 My 1930.

Some examples of interrelations of rocks and trees. Jour. N. Y. Bot. Gard. **31:** 141–148. *f. 3–7.* Je 1930.

Plant life south of the ice front during the Glacial Epoch. Jour. N. Y. Bot. Gard. **31:** 176, 177. Jl 1930. [Abstract of lecture.]

The Upper Cretaceous floras of Alaska [with a description of the plant-bearing beds, by George C. Martin]. Prof. Paper U. S. Geol. Surv. **159:** 1–123. *pl. 1–87*+*f. 1–5.* 1930.

Australia in the past. Jour. N. Y. Bot. Gard. **31:** 217–225. S 1930. [Abstract of lecture.]

One thousand miles down the Yukon by canoe. Jour. N. Y. Bot. Gard. **31:** 292–296. D 1930. [Abstract of lecture.]

Plant remains from a Pleistocene lake deposit in the upper Connecticut River valley. Brittonia **1:** 35–55. *pl. 1–11.* F 1931.

The big trees of California. Jour. N. Y. Bot. Gard. **32:** 238–240. O 1931. [Abstract of lecture.]

Records of Triassic fossils on Staten Island, New York, with descriptions of specimens. Proc. Staten Island Inst. Arts and Sci. **6:** 5–22. *pl. 1–9.* 25 N 1931.

Descriptions of new species of Tertiary cycads, with a review of those previously recorded. Bull. Torrey Club **59:** 169–189. *pl. 1–14+f. 1.* "Ap 1932" [3 My 1932].

Deserts of the Southwest. Jour. N. Y. Bot. Gard. **33:** 247–250. N 1932. [Abstract of lecture.]

THE NEW YORK BOTANICAL GARDEN

The curvature, symmetry and homologies of the sporocarps of Marsilea and Pilularia

DUNCAN S. JOHNSON[1]

(WITH PLATE 26)

The prime purpose of this paper is the correction of two errors that are almost universally made in describing the sporocarp of *Pilularia*. In the first place, while all current handbooks of the ferns, *quite correctly*, designate sections of the capsule of *Marsilea* that are perpendicular to the sagittal plane and parallel to the axes of the sori as *transverse sections*, like sections of *Pilularia* are everywhere called *longitudinal*. The latter designation is clearly quite erroneous from a morphological standpoint. A second mistaken assumption, made in practically all the handbooks is the assumption that the capsule of *Pilularia* is radial in its symmetry. The unfortunate results of these two misconceptions are that a detailed comparison of these two sporocarps and so the recognition of their very close homology has proved impossible.

A chief reason for the first error mentioned regarding the structure and homology of the mature sporocarp of *Pilularia* is the difference in the amount and the persistence of the curvature of the peduncle, in *Pilularia* itself and in the different species of the related *Marsilea*. The comparison of the development of the sporocarps in several species of these two genera makes clear the very exact homology between them, and the causes of the above-mentioned errors also become evident.

In the sporocarp of *Marsilea quadrifolia*, e.g., the development of this structure from a bifacial initial cell is known in more detail than for any other member of the genus. The youngest sporocarps of this species seen were nearly straight (Johnson, 1898,[1] fig. 25). Later the more rapid growth of the dorsal side of the peduncle, just below the capsule, bends the peduncle through almost 180°, which brings the ventral side of the capsule to lie nearly in contact with that of its own peduncle (Johnson, 1898,[1] fig. 31a). In consequence of this its soral canals, from pointing perpendicularly away from the axis of the peduncle, come to point directly toward the basal part of the peduncle. The capsule itself, meanwhile, remains practically straight. As this sporocarp matures the U-bend of the peduncle unbends through 90° or more, till the long axis of the ripe capsule, instead of being parallel to its own peduncle, comes to make a wide angle, often as great as 120°, with its own stalk. The soral canals thus come to point not toward the peduncle, but outward and downward at an angle of some 30° with it. The apical region of the capsule is at the end opposite that to which

[1] Botanical Contribution from the Johns Hopkins University, No. 120.

the peduncle is attached. This is the position of the capsule on the peduncle when the sporocarp is mature (fig. 3. cf. Alex. Braun, 1870, p. 702, fig. 3; Johnson, 1898,[1] fig. 44).

If now we compare the capsule of *Pilularia globulifera* with that of *Marsilea quadrifolia* we find that the peduncle of this *Pilularia* also bends markedly, just where it does in *Marsilea*,—but it bends in the *opposite* direction. When very young the sporocarp of this *Pilularia* is straight and when the soral canals are initiated they point, just as in *Marsilea*, ventrally and at right angles to the straight common longitudinal axis of the peduncle and of the capsule itself (fig. 4). Later, as the peduncle and capsule become more clearly differentiated, the peduncle begins to curve backward and it continues this until maturity, when its form becomes fixed (figs. 5, 6). The curvature here is far less than the primary curvature in *Marsilea*. In fact the change in direction of the soral axes is rarely more than 60° instead of the 180° of *Marsilea quadrifolia*. Finally there is no reversal of this primary curvature in this *Pilularia* such as we saw in *Marsilea*. The result of this bending in *Pilularia*—one is inclined to call it a straightening out, when seeing the relation of capsule to peduncle at maturity—is that the outer ends of the 4 soral canals come to have a nearly terminal position. In other words, their axes make an angle (on the ventral side) of 160° with the peduncle and so come within 15 or 20° of being parallel to the axis of the peduncle. But the canals point upward, not downward as in *Marsilea* and the apical region of the capsule (location of initial cell) is directed backward and upward at an angle of 130° with the peduncle (fig. 6 at A). It is because of this curvature of the peduncle of *Pilularia globulifera* that sections of the capsule cut perpendicular to the soral canals have been, quite erroneously, thought of as *transverse* sections and so labelled in all the handbooks. They are in reality nearly longitudinal and horizontal ones morphologically. (Fig. 7 "MN"). For the same reason sections parallel to these canals and perpendicular to the sagittal plane are *transverse not longitudinal*—in the same sense as in *Marsilea* (Figs. 10, 11, 12 cf. Johnson, '98,[1] Figs. 31, 32, 33). Nevertheless such sections of *Pilularia* are labeled *longitudinal* in all the handbooks (e.g. Luerssen, fig. 191, p. 617; Meunier, 1887, figs. 12, 13, 53; Engler and Prantl, 1902, figs. 227, 229B; Lotsy, 1909, figs. 427, 428; Bower, 1926, fig. 463; Goebel, 1882, figs. 2, 7, 8; Campbell, 1918, figs. 254[E], 256A; 1893, p. 143 and figs. 4, 6, 8, 9).

In a *Pilularia* recently collected in Venezuela by Pittier, (probably *P. americana*) the mature sori make an angle of but 75° or 80° with the peduncle instead of the 160° we have found in *P. globulifera*. That is, there is no such considerable bending backward or "straightening out" of the

peduncle of this species as there is in *P. globulifera*. If, which is probable, the soral canals are lateral in origin, as in *P. globulifera*, there must in this species be a slight bend forward of 10° or 15° instead of the marked backward bend of the peduncle found in *P. globulifera*. There can hardly be so strong a forward bend as is stated by Campbell (1893, p. 142).

In *Pilularia minuta*, which I have recently been able to study, the capsule itself develops much as in *P. globulifera*. The soral canals at first point ventrally but the curving of the peduncle is here a strongly hyponastic one, which brings the two soral canals of this species to point downward toward the very base of the peduncle. This brings the originally apical region of the capsule to face perpendicularly away from the peduncle against which its basal side lies. It is evident then that transverse sections of the mature capsule of *P. minuta*, i.e. sections parallel to the soral canals and perpendicular to the sagittal plane, will be in a plane nearly parallel to the peduncle. But the soral canals here point downward, not nearly upward from the peduncle as in *P. globulifera* (figs. 8, 9, 10). On the other hand, morphologically longitudinal sections of the capsule, i.e. those perpendicular to the soral canals, are actually transverse to the peduncle (Johnson 1933[1] figs. 14, 16, 19, 22, 28). None of the mature capsules of my material were erect, as they were reported to be in this species by Alex. Braun. In the degree and direction of curvature of its peduncle then *P. minuta* differs markedly from *P. globulifera*, and also from *P. americana*. Moreoever, the first bending of the peduncle in all three species of *Pilularia* is permanent. There is no reversal of the bending, such as occurs in *Marsilea quadrifolia*.

In general then wherever sections along the soral canals of *Pilularia minuta* or *P. americana* have been illustrated in monographs or handbooks, they have been mistakenly called *longitudinal*, even where they were directly compared with similar sections of *Marsilea* which were labelled *transverse*. This error has evidently been due to the assumption that these capsules correspond in *every way* to that of the wrongly interpreted one of *P. globulifera*.

Much this same diversity, in the degree of curvature of the peduncle, that we have described for *Pilularia* is also found in the different species of *Marsilea*. Thus while the angle between the peduncle and the axis of the sorus in *Marsilea quadrifolia* is about 30°; in *M. nardu* this angle is 40° and finally in *M. salvatrix* it is nearly or quite 90° and the peduncle is attached to the middle of the end of the capsule. In *M. polycarpa* on the other hand, as figured by Alex. Braun, the axis of the sorus becomes nearly parallel to the peduncle showing a forward curvature of 90°, while in *M. Brownii* the peduncle appears never to have straightened out at all from

its first curvature and the soral canals point downward and inward toward the base of the peduncle. (figs. 13, 14, 15, 16.) The mistaken interpretation of the structure of the capsules of the *Pilularia* referred to above would probably not have been made so generally if their capsules had been compared with those of *several* species of *Marsilea* instead of with that of *Marsilea quadrifolia* alone.

In the third genus of the Marsiliaceae, *Regnellidium*—as figured by Lindman—the angle between peduncle and soral axis is 90°. Moreover this capsule appears as if attached to the peduncle by its long (dorsal) side and not by its end as it is in *M. salvatrix* referred to above. (See Lindman, 1904, fig. 3^{A}).

SYMMETRY OF THE CAPSULE OF PILULARIA

The second mistaken conception referred to regarding the capsule of *Pilularia*, namely that it is radial in symmetry, is readily proved erroneous by a study of the development of the sporocarps of either of the three species referred to above. Such a study shows at once that the sporocarps of *P. globulifera* and *P. minuta* (and so probably those of all other species) are from the first *zygomorphic*, or *bilaterally symmetrical* structures. They are closely identical in fundamental plan with that of *Marsilea quadrifolia*. Thus the capsule of *P. globulifera* is developed from a bifacial initial cell, the approximately semicircular segments of which meet at the "median wall" which latter is clearly seen in all sections of the young capsule that are either transverse or horizontal. This apical cell which is at first terminal, is gradually pushed around toward the dorsal side by the more active elongation referred to above, of the ventral side of the capsuel (figs. 4, 5, 6). The four sori, as are those of *P. americana*, are distributed two on each side of the median or sagittal plane of the capsule. There is a marked pit and a tubercle on the midline of the dorsal surface of the capsule, just above where the peduncle joins it (Johnson, 1898,[2] Fig. 33). Internally there is an overlap of two layers of the hypodermis, a right angle bend and a Y-like forking of the vascular bundle of the peduncle, and a sclerenchyma strand lying against the ventral face of this bundle. All of these internal structures also lie in the sagittal plane of the fruit, and so serve to further emphasize its bilateral symmetry.

The sporocarp of *Pilularia minuta*, is, like that of *P. globulifera*, evidently due primarily to the activity of a two-sided initial cell, like that actually seen in its young leaf (Johnson 1933, figs. 6, 8). This is indicated: (1) By the clearly marked "median wall" in its capsule, that is seen in each transverse and each horizontal section; By the plan of its capsule, which has one sorus and one soral canal in each half; (figs. 7, 8, 10), by its

vascular bundle which splits to a right and left fork just after entering the capsule. All these *paired* structures show this capsule to be *bilaterally symmetrical* (See Johnson, 1933, figs. 18, 25, 27, 28). *Another series* of *unpaired* structures, all of them located on the midline of the dorsal (abaxial) surface of this capsule, emphasize still further its zygomorphic or dorsiventral symmetry (fig. 9). These include: the external tubercle, of decidedly specialized internal structure; (1933, figs. 22, 39); the "pit" just above this tubercle; the *overlap* of two narrow flaps of the thickened hypodermis (See Johnson, 1933, figs. 39–42) and the right angled bend of the vascular bundle as it enters the wall of the capsule, just below this overlap.

Each of the structural features of the capsule of *Pilularia minuta* referred to in the last paragraph, the paired and the unpaired ones, has its close counterpart in the capsule not only of *Pilularia globulifera*, but likewise in that of *Marsilea quadrifolia*.

From all the facts given above regarding the sporocarps of these two genera, it is clear that these are, from the beginning of their development, zygomorphic or bilaterally symmetrical structures. This is true of both peduncle and capsule (See Johnson, '98,[2] pp. 7, 11). The existence of this type of symmetry in the sporocarp of *Marsilea* has long been generally accepted (Mettenius, 1846, p. 33; Alex. Braun, 1870, p. 696). Braun and Goebel, however, seem to be the only students of *Pilularia* to suggest the occurrence of dorsiventral symmetry in the sporocarp of *Pilularia*. Braun (1870, p. 706) gives no detailed statements of the evidence for this view but, after stating categorically that the capsule of *Marsilea* has a dorsal and a ventral side, he merely adds—"und nach der Nervatur möchte ich dasselbe von *Pilularia* glauben." Braun, though he does not say this, probably thought of the plane of symmetry as passing through the stalk and as separating the two arms of the basal fork of the vascular bundle, which bundle he actually figured (Braun, 1870, p. 705, fig. 3). Whether he, as later writers have done, regarded the region of the mature capsule which is nearly opposite the point of its insertion on the peduncle as the morphological apex of the sporocarp is not entirely clear. But this seems probable from his statement regarding the position of the sori in the capsule of Pilularia, of which he says (Braun, 1872, p. 678) "Sori in sporocarpio globoso *longitudinales*." In contrast he says of *Marsilea*—"Sori in sporocarpio zygomorpho *transversales* pinnatim disposita." (Braun, 1872, p. 668). These two statements seem to show that he regarded the plan of the sporocarp of *Pilularia* as different from that of the "zygomorphic" *Marsilea*. At all events, the view that regards the end of the mature capsule of *P. globulifera* opposite the point of its insertion on the peduncle

as the morphological apex of the capsule, is the view which has been practically universally accepted by later workers. This is probably due to the fact that in this species the axes of the originally transverse sori came, finally, to lie nearly in line with the peduncle. Thus Goebel (1882, p. 777) says "a cross section of a young *Marsilea* fruit is strikingly like a longitudinal section of a *Pilularia* fruit." In his Plate IX, Fig. 2, he designates a section of the capsule of Pilularia at right angles to the soral canals as a *transverse* section. Even in the last edition of the Organographie der Pflanzen (Goebel, 1930, p. 1286) speaks of a section perpendicular to the soral canals and the meridional vascular bundles of *P. globulifera* as *transverse*. Elsewhere in this volume (p. 1281) Goebel does speak of the sporocarp of *Marsilea* and *Pilularia* as always dorsiventral but he gives no evidence to support this and later remarks that in *Pilularia* this symmetry *is not evident externally*. Meunier (1887, figs. 13, 47, 50) and Campbell (1893, p. 142) evidently regard the capsules of *P. globulifera* and *P. americana* respectively as radial in symmetry. Thus Meunier (1887, pp. 359, 360) says each of the 4 lobes of the sporocarp, one "above" each sorus, has a separate initial, which is said to arise independently, *after the initial of the sporocarp as a whole has ceased to function*. He gives as a typical longitudinal section of the sporocarp (1887, fig. 12) one diagonal to the sagittal plane which thus passes through the middle of one sorus in the left half of the capsule and of another in the right half, and misses altogether the tubercle, the pit and the overlap of the hypodermis, all of which, as we have seen, lie in the median plane. Campbell on the contrary, (1893, p. 142) thinks the original apical cell of the whole sporocarp occupies the tip of *one* of the *four* lobes, while the *other three arise separately*:—one on a line directly below the initial and one on each side of this line. If this were true, the plane of symmetry must really, of course, pass through the first two lobes mentioned and so through two diagonally opposite sori of the mature capsule. Lindman (1904, p. 9) contrasts his new genus *Regnellidium*, which he says is bilaterally symmetrical like *Marsilea*, with *Pilularia*, in which latter he says the sori are "whorled."

All these views of the symmetry and of the origin of the lobes of the sporocarp of *Pilularia* are, as a matter of fact, erroneous, as was shown by a detailed study of the development of the capsule of *Pilularia globulifera* (Johnson, 1898,[2] pp. 7, 18–22, figs. 14, 24, 31, 33). A recent study of the development of the sporocarp of *Pilularia minuta* has confirmed the results and the interpretations published earlier regarding *P. globulifera*. The prime differences between the capsules of these two *Pilulariae* and that of *Marsilea quadrifolia*, as shown by the two studies mentioned, are in the number of sori formed on each side of the midplane and in the posi-

tion of the mature capsule on the peduncle. In all other essential details of structure the mature capsule of a *Pilularia* corresponds with that of a *Marsilea*. Moreover, the sporocarp of *Pilularia* is like that of *Marsilea* in being developed by the activity of a single, bifacial initial, with convex faces.

Another question regarding these genera that is not yet settled to the satisfaction of all workers is that of the homologies between the sterile and fertile divisions of the leaf—the foliage leaf and the sporocarp. The generally accepted view is that the sporocarp is a fertile portion ("lobe" or "leaflet") of the leaf or frond, comparable with the fertile portion of the sporophyll of e.g. an *Aneimia* or *Lygodium*. This has led to the further assumption that the sporocarp of *Marsilea* or *Pilularia* is a fertile pinna, comparable except for its sporangia with one or more of the 4 terminal leaflets of the sterile leaf of *Marsilea* (See Goebel, 1882, p. 773; 1930, pp. 1283). The occurrence in a longitudinal series of the 10 or 15 sporocarps of *M. polycarpa* is often cited as convincing evidence that these are equivalent to the pinnae of a once-compound fern frond. Thus Goebel (1930, p. 1283) regards each sporocarp of *Marsilea* as a single pinna. Campbell, on the other hand, (1893, p. 143) says the 4 prominences on the young capsule of *Pilularia*, one for each locule, "are beyond doubt to be regarded as 4 leaflets," and says the ripe capsule splits to 4 valves corresponding to these lobes or leaflets. Even in his latest work on this form (Campbell, 1918, p. 435) seems still to hold to the above mentioned interpretation. His view, stated above, is that one of the lobes or pinnae, which he thinks composes the capsule, arises from the original initial of the sporocarp and a second one on the mid-line of the ventral surface. Both these suggested modes of origin of a "leaflet" are quite different from the origin found in *Marsilea* and from any known in any related fern.

Bower in speaking of the homology of the capsule of *Marsilea* says (Ferns II, 1926, p. 188)—"the hypothesis seems tenable that the sporocarp (capsule) consists of a rachis bearing two rows of pinnules: this is indicated by the venation."—This view is like that of Campbell in regarding the capsule as composed of several pairs of pinnae fused into one structure.

Before any one of these views can be accepted, however, it must be shown that it is in accord with certain known facts concerning the structure and development of the sporocarps of *Marsilea* and *Pilularia*. We have seen that the sporocarp of *Marsilea* is initiated like that of *Pilularia* by a single, bifacial initial with convex faces. In other words, the initial of the sporocarp is precisely like that of the leaf as a whole (See Johnson, 1898,[1] figs. 4, 18, 21, 34). The pinna of the sterile leaf of *Marsilea* on the contrary is formed by the activity of several to many 5-sided marginal cells, each

like a 100° sector of a disk, whose thickness is about 1/5 of its diameter (Johnson, 1898,[1] figs. 19, 20). Though the sporocarp may ultimately be shown to be a fertile pinna, the writer can see no evidence from these facts of development for so regarding it. Another clear indication that the sporocarp is often something more complex than a single pinna, or a group of fused pinnae of one order, is the fact that the primary sporocarp of a leaf may often give rise to a secondary sporocarp from an initial arising in a marginal cell of the stalk of the primary one. Not infrequently a tertiary one also may arise thus from the peduncle of the secondary sporocarp. For those who think of the sporocarp as a pinna, these instances, which they seem to have overlooked, must be regarded as cases of twice or thrice compound foliar structures. Such an interpretation does not, to say the least, make it any easier to settle the homology between the sporocarp and the sterile segment of its own leaf or the affinities of the Marsileaceae with those other Filicales such e.g. as the Schizaeaceae with which they have been thought to be related.

SUMMARY AND CONCLUSION

The sporocarps of the *Pilulariae* like those of the *Marsileae* are shown by their development to be zygomorphic structures; i.e. they are bilaterally symmetrical with reference to a *median* or *sagittal* plane.

The paired young soral canals open, in all cases, one of each pair on each side of the midline of the ventral face of the capsule.

The tubercle, pit, overlap of the hypodermis, and Y-like forking of the vascular bundle *all* lie in the midplane of the capsule.

The bending of the peduncle is always in this same plane—the sagittal one.

The *direction* of the primary bending is different in *Marsilea quadrifolia* and *Pilularia globulifera*, being hyponastic in the former and epinastic in the latter.

The amount of the bending is relatively constant for each species, but differs strikingly in different species of each genus.

The bending is sometimes permanent at the farthest limit reached, while in other cases the primary bending may be largely reversed or "unbent" before the capsule matures.

If the zygomorphic symmetry of the sporocarp of *Pilularia* is not forgotten, as it usually has been when comparing it with *Marsilea*, it becomes clear that its capsule is very closely equivalent to that of *Marsilea* except that it has but two pairs of sori in each half in *P. globulifera* and but one sorus on each side in *P. minuta*, instead of six or more sori in each half of the capsule, that are found in *Marsilea quadrifolia*.

The details of development of the sporocarp in both *Marsilea* and *Pilularia* and the occurrence of secondary, and even tertiary sporocarps in *Marsilea* seem to give no support to the view that the sporocarp of the Marsileaceae is to be regarded as a fertile pinna equivalent in origin to the sterile leaflet of *Marsilea*.

JOHNS HOPKINS UNIVERSITY

Literature cited

Bower, F. O. 1926. The Ferns. vol. II, Marsileaceae. 176–192. Cambridge Univ. Press.

Braun, A. 1870. Neuere Untersuchungen ueber die Gattungen *Marsilia* und *Pilularia*; Monats. Köngl. Akad. Wiss. Berlin, 653–753.

————. 1872. Nachträgliche Mittheilungen ueber die Gattungen *Marsilia* und *Pilularia*. Monats. Köngl. Akad. Wiss. Berlin, 635–679.

Campbell, D. H. 1893. The development of the sporocarp of *Pilularia americana*. Bull. Torr. Club **20**: 141–148.

————. 1918. Structure and development of the mosses and ferns. 3rd. Ed. N. Y.

Engler and Prantl. 1902. Natürl. Pflanzenfam. 1^4: 403.

Goebel, K. von. 1882. Ueber die "Frucht" von *Pilularia globulifera*. Bot. Zeit. **40**: 771.

————. 1930. Organographie der Pflanzen. Dritte Aufl. pp. 1260, 1283.

Johnson, D. S. 1898.[1] On the leaf and sporocarp of *Marsilea quadrifolia*. Ann. Bot. **12**: 119–145.

————. 1898.[2] On the leaf and sporocarp of *Pilularia*. Bot. Gaz. **26**: 1–24.

————. 1933. Structure and development of *Pilularia minuta*. Bot. Gaz. **95**: 104–127.

Lindman, C. A. M. 1904. Regnellidium novum genus Marsileacearum. Arkiv. Bot. III, No. 6, 1–14, *ff. 1–10*.

Lotsy, J. P. 1909. Vorträge ueber Botanische Stammesgeschichte **2**: 621–634. Jena.

Luerssen, C. 1889. Rabenhorst Kryptog. Flora **3**: 617.

Mettenius, G. 1846. Beitrage zur Kenntniss d. Rhizokarpeen. 1–65. Frankfurt.

Meunier, A. 1888. La Pilulaire. Étude anatomico-génétique du sporocarpe chez la *Pilularia globulifera*. La Cellule, **4**: 319–400.

Explanation of plate 26

Fig. 1. Right side of young leaf of *Marsilea quadrifolia* bearing very young, slightly bent sporocarp. ×11.

Fig. 2. Right side of somewhat older sporocarp of *M. quadrifolia* showing apex of capsule bent down against base of its peduncle. ×15.

Fig. 3. Inner surface of left valve of mature, emptied capsule of *M. quadrifolia* showing outline, with pit and tubercles, the vascular system and the internal structure of the basal region of the capsule. ×6.

Fig. 4. Ventral surface of very young sporocarp of *Pilularia globulifera* showing its bilateral symmetry, the initial of the sporocarp and those of the sori. ×170.

Fig. 5. Approximately sagittal section of a half-grown sporocarp of *P. globulifera* passing far enough to the right of the median plane to cut through the two sori of the right half of the capsule. ×170.

Fig. 6. Median sagittal section of a ripe capsule of *P. globulifera* passing through the indusium between the two sori of the left half and the two of the right half of the capsule. ×13.

Fig. 7. Left side of a half-grown sporocarp of *Pilularia minuta* (cleared in glycerine) showing outline of capsule, sporangia, basal wall and pedunclar vascular bundle. ×80.

Fig. 8. Abaxial (apical) face of nearly mature capsule of *P. minuta* showing bilateral symmetry as indicated by its soral papillae and position of sporangia. ×25.

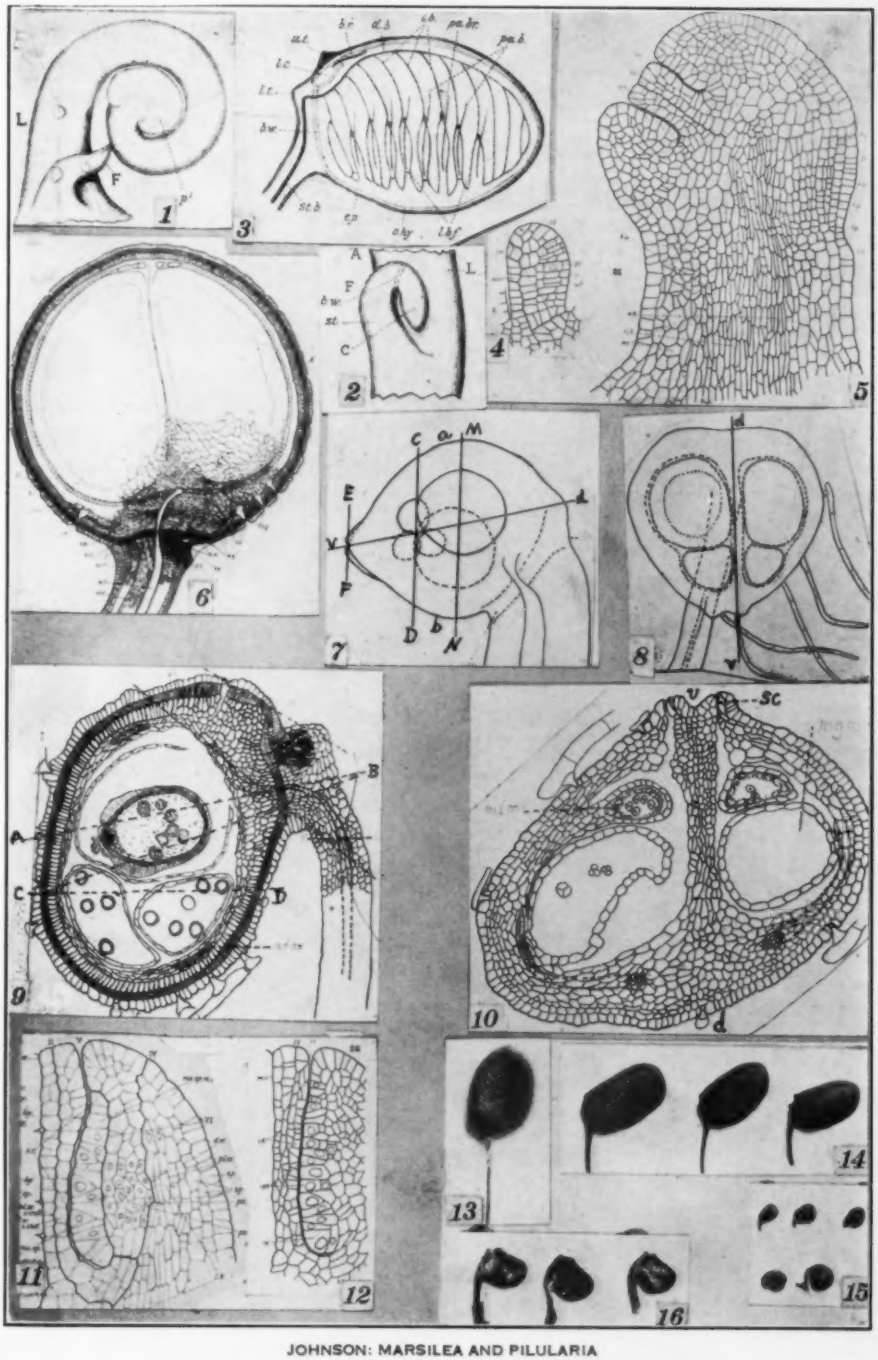
Fig. 9. Nearly sagittal section of mature capsule of *P. minuta* showing outline, including pit and tubercle; also course of vascular bundle, overlap of hypodermis in basal wall and the relative position of the micro- and megasporangia in the right sorus. ×50.

Fig. 10. Transverse section of a half-grown capsule of *P. minuta* (along line "dv" of Fig. 7) indicating the bilateral symmetry by the paired soral canals and papillae and the micro- and megasporangia of right and left locules. ×100.

Fig. 11. Part of a transverse section of a young capsule of *Marsilea quadrifolia* through (and longitudinal to) a soral canal and a sorus with 4 megasporangium initials. ×230.

Fig. 12. Part of a transverse section of a young capsule of *Pilularia globulifera* showing soral canal and sorus with megasporangium initials. Note identity of position of these structures with those of *Marsilea* shown in Fig. 11. ×180.

Figs. 13–16. Lateral views of the capsules respectively of *Marsilea salvatrix*, *M. nardu*, *M. polycarpa* and *M. Brownii* showing in each the position of the capsule in relation to the peduncle and in Fig. 14 the direction of the sori in the capsule. ×1½.



JOHNSON: MARSILEA AND PILULARIA

UNIV. OF MICH.

The constancy of cultural characters and pathogenicity in variant lines of Ustilago zeae[1]

E. C. Stakman, L. J. Tyler, and G. E. Hafstad

(with plates 27 and 28)

In 1929 Stakman, Christensen, Eide, and Peturson[2] published the results of extensive studies on mutation and hybridization in *Ustilago zeae* (Beckm.) Ung. It was shown that some unisexual lines, therefore presumably haploid, produced large numbers of new lines as a result of sectoring in colonies growing on artificial media in Erlenmeyer flasks. It was argued that the origin of the new lines could best be explained on the basis of mutation, although it was admitted that an unusual type of segregation also might be responsible. In any case, the change seemed to be genotypic, as the new characters were relatively constant and there was evidence from studies on hybridization that the changes involved the nucleus. The writers now are making studies designed to elucidate some of the problems involved. In the meantime, further evidence of constancy of "mutant" characters has been obtained.[3] As the results seem significant, they are presented in this paper.

A special study was made of the degree of constancy of cultural characters and pathogenicity of several "mutant" lines of "W. Va. A8" isolated in 1928 and grown on artificial media since that time. The early history of some of the lines is given in a previous publication[2] (P.1, p. 10–14, and fig. 1). W. Va. A8 was isolated from a collection of smut obtained from Dr. R. J. Garber of West Virginia. Several monosporidial isolations were made in January, 1928, and, as the cultures developed from them appeared alike, one line was selected for further study. From this monosporidial line 162 variants were isolated by the fall of 1928, and some have been kept continuously in culture since they first appeared. Most of those discussed in this paper were isolated in the early spring of 1928, although some appeared during the summer; hence the lines are now from 4½ to 5 years old.

Some of the lines have produced numerous sectors, but, despite this

[1] Paper No. *1175* of the Journal Series of the Minnesota Agricultural Experiment Station. Supported in part by a grant from the Graduate School of the University of Minnesota.

[2] Stakman, E. C., J. J. Christensen, C. J. Eide, and Bjorn Peturson. Mutation and hybridization in *Ustilago zeae*. Minn. Agr. Exp. Sta. Tech. Bul. 65. 1929.

[3] Stakman, Christensen, Eide, and Peturson designated as mutants the variants that arose as sectors, although they qualified the term (Minn. Tech. Bul. 65, p. 53 et seq.). The present writers also think there is good evidence that new lines arise through mutation, but there remains the possibility of delayed segregation. Therefore the term variant is used, but the viewpoint remains the same.

fact, it has been possible to maintain the original types in culture by the simple expedient of growing the cultures in flasks and transferring from the parental type and from the sectors separately. Some of the lines that do not sector abundantly were grown in tubes much of the time, only occasionally in flasks; and all of them were grown in tubes some of the time. As it is difficult to detect sectors in tubes, it seems all the more remarkable that the original types were maintained for a period of approximately five years.

Fourteen of the lines of the W. Va. A8 series have been grown periodically in duplicate or triplicate flasks on several kinds of media. They were always distinct from each other in appearance, and, by comparing their characters with those recorded in descriptions and photographs about five years ago, it is evident that they are as nearly identical in appearance with the original cultures as could be expected under the circumstances. For it is, of course, impossible to duplicate exactly the conditions under which cultures are grown four or five years apart, and the cultural characters of a line may vary considerably with composition of medium, temperature, moisture, light, and other environmental factors.

In plate 27 are shown 8 lines, all of them isolated about four and a half or five years ago, except A8-10-1 and A8-3-1-1, which appeared more recently as sectors in colonies of A8-10 and A8-3-1, respectively. As some of the lines differ from each other in color, the differences do not appear as distinct in the photograph as they actually are. The plate does show, however, that the eight lines, all of them descendants of a single unisexual sporidium, were still different from each other when photographed in October, 1932.

Plate 28 shows that the lines not only differ from each other but that they also have retained their distinctive characters. The plate was made from a combination of photographs taken at different times. On the left are shown cultures of three lines on potato dextrose agar, photographed in September, 1929; in the middle, cultures of the same lines on potato dextrose agar, photographed in October, 1932; and on the right, the same lines on potato malt agar, photographed in December, 1932.

Each vertical series shows the differences between the three lines at a given time and on the same medium, while each horizontal series shows the range of variability in the appearance of colonies of one line at different times and on different media. As the photographs were taken at different times and the enlargement is not the same in all cases, the differences in the appearance of colonies of the same line are somewhat accentuated. Despite the variability, certain characteristics of color, topography, margin, and surface markings distinguish each of these lines, as well as the others, when grown under reasonably uniform conditions.

Stakman, Christensen, Eide, and Peturson[4] emphasized the fact that there may be great phenotypic variability in cultures of monosporidial lines, but that the lines are constant genotypically except as new ones arise through what appears to be mutation. The accuracy of this conclusion is attested by a study of Plate 28. There is considerable variability in the appearance of cultures of each line. This is accounted for partly by the fact that the 1932 series on potato dextrose agar grew during August and September, when the weather was extremely hot. The agar therefore dried out unusually rapidly and the colonies were somewhat subnormal in size and not so characteristic in appearance as usual. The colonies on potato malt agar, grown later in the fall, are of about average size, and the difference in their appearance is what would be expected on this medium. It is important to bear in mind, therefore, that the three colonies of each line grew under quite different conditions. Considering this fact, the resemblances are striking. Furthermore, cultures of each of the lines were compared periodically with photographs and descriptions of the same lines made in 1928 and the agreement always was very close, the appearance of the colonies often being identical with that in the photographs. The senior writer, who isolated the lines originally and studied them closely, never had the slightest difficulty in picking cultures of these lines out of a random assortment of cultures of many different lines.

The characters of colonies of the three lines on potato dextrose agar as recorded September 1, 1929, are given in Table 1.

In September, 1932, the color of A8-3-1 still was distinctly grayish olive and yellowish white, that of A8-5-5 was orange buff, and that of A8-5-3-3-2 was white, with a tinge of purplish brown near the center. There never would have been any difficulty in distinguishing the lines from each other by color alone. The characteristic elevation, luster, surface and topography, and edge of colonies of the same line also were so persistent as to justify the conclusion that these characters are due to genetic factors. If the colonies in the 1929 and 1932 series on potato dextrose agar are compared carefully, it will be seen that they are very similar in essential characters, although the expression of the characters differs somewhat for the reasons already mentioned (Plate 28). On potato malt agar growth usually is more rapid than on potato dextrose agar, colonies become larger and coarser, but the color is about the same and the other characters are of the same general nature as on potato dextrose agar. That the characters of the colonies are due to the interaction of genetic and environmental factors is obvious; in fact the elementary principle on which this statement is based is illustrated beautifully by the behavior of these lines of *U. zeae*.

[4] Minn. Tech. Bul. 65. 1929.

TABLE 1

Cultural characters of three lines of W. Va. A8 derivatives growing on potato dextrose agar. Taken from Minnesota Technical Bulletin 65, Table IV, p. 17.

LINE	DIAM. IN MM.	COLOR	ELEVATION	LUSTER	SURFACE AND TOPOGRAPHY	EDGE
A-8-3-1	56	Gray drab on central knob; surrounded successively by olive drab, gray drab, and dirty yellowish-white zones	Convex-umbonate	Dull to cretaceous	Central area rugulose; surrounded by coarsely rugose zone, and broad marginal zone almost flat; radial folds extending 1 centimeter from central area but not reaching margin	Fimbriate
A8-5-5	55	Orange buff	Convex	Dull	Contoured; regular radial furrows in marginal zone	Entire
A-8-5-3-3-2	50	White; faint purple brown near center	Convex	Cretaceous	Verrucose	Slightly fimbriate

There is additional circumstantial evidence from study of these lines that sectoring often is due to mutation rather than segregation. Some, notably A8-7, A8-8, A8-9, and A8-10, never had produced sectors from the time they were isolated in February, 1928, until November, 1931. Then sectors appeared in A8-9 and A8-10, after which A8-10, particularly, showed a tendency to sector occasionally. One of the new lines, A8-10-1, is shown in Plate 27 above its parent, A8-10. It seems improbable that segregation would be delayed for almost three years. Furthermore, A8-3-1, which appeared as a sector in a culture of A8-3 in June, 1928, was kept under close observation because of its very characteristic appearance, and it never produced sectors until September, 1932, when several appeared. One of them was especially distinct and was studied carefully. The basic color of the parent, A8-3-1, was light grayish olive, while that of the variant, A8-3-1-1, was almost ivory white; aerial growth was fairly abundant on colonies of the parent, while there was very little on those of the variant; the parent line produces a light vinaceous color in the medium, while the new line does not discolor the medium. The new line therefore appears to have lost factors for aerial growth and pigmentation of the medium. Here again it seems unlikely that segregation would have been delayed more than four years. The appearance of the two lines is shown in Plate 27.

The above facts support statements made by Stakman, Christensen, Eide, and Peturson[3] (p. 50) to the effect that "mutant" lines of *U. zeae* may be quite variable phenotypically but are genotypically distinct and constant except as they may change by "mutation."

Experiments also were made to ascertain whether the pathogenicity of the variant lines had remained constant. All of the lines are unisexual; consequently normal infection and production of chlamydospores do not result when corn is inoculated with a single line. Therefore, the only method of determining pathogenicity is by inoculating with combinations of lines of different sex. In the winter of 1928–29 Golden Bantam sweet corn had been inoculated hypodermically with W. Va. A8 and some of its derivatives in combination with Minn. A and Italy A1. In the late fall of 1932 Northwestern Dent corn was inoculated with the same combinations, as shown in Table 2. The methods used were similar to those previously described by Stakman and Christensen.[5] The notes on the two series inoculated several weeks apart in 1932 were taken without reference to the results obtained in 1928–29. Furthermore, the pots inoculated with the different combinations were designated by key numbers in order to avoid personal bias in recording the degree of infection. When the results were compared with those obtained almost four years previously, it was found that there was surprising agreement, all the more remarkable and noteworthy because different varieties of corn had been inoculated.

The results (Table 2) show clearly that the pathogenicity of the lines had not changed, the degree of infection caused by particular combinations of lines being very uniform throughout.

In 1928–29 all of the lines, except W. Va. A8-5-3-3-2, which caused no infection either with Minn. A or Italy A1, caused heavier infection in combination with Minn. A than with Italy A1. This was true also in 1932. W. Va. A8-1-1 so consistently produced heavier infection than its original ancestor, W. Va. A8, both with Minn. A and Italy A1, that it appears to have gained factors for sex or pathogenicity, or both, or to have lost inhibiting factors. W. Va. A8-5-5 and W. Va. A8-5-3-3-2 clearly are less virulent in both combinations than the original ancestral line, W. Va. A8. Apparently both are devoid of certain factors possessed by the other two W. Va. lines.

It is evident that different combinations of lines may differ in virulence. And it is clear also that these differences must be due to genetic factors; otherwise they could scarcely be so consistent. W.Va. A8-1-1 x Minn. A was the most virulent combination in 1928–29 and again in 1932. W. Va. A8 x

[5] Stakman, E. C., and J. J. Christensen. Heterothallism in *Ustilago zeae*. Phytopath. *17:* 827–834. 1927.

TABLE 2

Results of inoculating Golden Bantam corn hypodermically with combinations between certain monosporidial lines of Ustilago zeae in 1928–29 and Northwestern Dent corn with the same lines in 1932.

LINES	MINNESOTA A			ITALY A1		
	1928–29	1932		1928–29	1932	
		SERIES 1	SERIES 2		SERIES 1	SERIES 2
W. Va. A8	$\frac{11}{12}$ M+	$\frac{12}{18}$ M+ to I	$\frac{9}{18}$ M+	$\frac{9}{11}$ I to S+	$\frac{10}{16}$ I to M	$\frac{9}{18}$ I to S
W. Va. A8-1-1	$\frac{10}{10}$ M++	$\frac{14}{15}$ M+	$\frac{16}{20}$ M++	$\frac{8}{10}$ M+	$\frac{10}{11}$ M+	$\frac{11}{17}$ M+
W. Va. A8-5-5	$\frac{7}{11}$ I to S−	$\frac{7}{17}$ I	$\frac{7}{18}$ I to S	$\frac{0}{11}$	$\frac{1}{20}$ I	$\frac{3}{20}$ I[a]
W.Va.A8-5-3-3-2	$\frac{0}{15}$	$\frac{0}{19}$	$\frac{0}{22}$	$\frac{0}{11}$	$\frac{0}{19}$	$\frac{1}{22}$[b]

[a] = no spores; [b] = probably accidental

The lines crossed with Minn. A and Italy Al are listed in the vertical column on the left in the table. The results are expressed in the form of a fraction, the denominator indicating the number of plants inoculated and the numerator the number that became infected. Inoculations also were made with each line singly, but no infection resulted, showing that all are uni-sexual.

The degree of infection is indicated as follows:

I Indicates incipient infection, that is, decided chlorosis and sometimes slight swellings; usually, however, without the production of chlamydospores

S indicates small galls

M indicates medium size galls

+ and − after letters indicate fluctuations within the class. M++, for example, means galls which are near the upper limit of medium size; S− means that the galls were very small. The first letter indicates the predominant type of infection.

Minn. A and W. Va. A8-1-1 x Italy A1 probably do not differ appreciably from each other, as both caused the same degree of infection in 1928–29 and 1932. W. Va. A8-5-5 x Minn. A caused only very weak infection in all three series of inoculations, the degree of infection being virtually the same each time. W. Va. A8-5-5 x Italy A1 caused no infection in 1928–29, and produced only a few very minute galls in 1932, without producing chlamydospores, however. This very slight difference may be due to normal variability, or Northwestern Dent corn may be slightly more susceptible to this combination than Golden Bantam.

Not only did the W. Va. lines remain constant in pathogenicity, but Minn. A and Italy A1 must also have remained constant, since they entered into the dikaryotic combinations which produced the same degree of infection at the different times. It is clear that there was no appreciable diminution in virulence of any of the lines as a result of having been grown for nearly four years on artificial media subsequent to the time the first inoculations were made.

The results of the inoculations strengthen the conviction that, in the case of *U. zeae*, new lines arising by sectoring in cultures are the result of genotypic changes, which sometimes involve factors for sex and pathogenicity as well as cultural characters. This supports the conclusions previously reached in the study of constancy of cultural characters. Furthermore, the fact that none of the variants was of entirely different sex from the original line suggests that they arose through mutation rather than delayed segregation.

SUMMARY

1. From a single monosporidial, unisexual line of *Ustilago zeae*, W. Va. A8, 162 distinct lines arose in 1928 as sectors in colonies of the original line and its variant derivatives.

2. Fourteen variant lines have been cultured on artificial media from early in 1928 until the present time. While they are variable phenotypically, distinctive cultural characters have persisted so definitely as to justify the conclusion that each of the lines constitutes a distinct biotype, from which new biotypes may, however, arise by sectoring.

3. Some of the variant lines produced no sectors for about three years, when several distinct ones appeared, from which new lines were isolated. This supports the idea that sectoring results from mutation rather than delayed segregation, although delayed segregation may sometimes occur.

4. The pathogenicity of the original line, W. Va. A8, and several of its derivatives was tested early in 1928, by mating them with Minnesota A and Italy A1. It was evident that some variants differed from A8 and each other in factors for sex and pathogenicity, although none of the variants combined with the original line and each other, indicating that there had not been a complete change of sex. This suggests that they arose through mutation rather than segregation. Late in 1932 inoculations were made with the same combinations of lines, and the results were almost identical with those obtained almost four years previously. This again indicates that the variant lines resulted from genotypic changes and are new biotypes.

5. It is evident that a large number of biotypes may arise from a single unisexual, monosporidial line, by what appears to be mutation. They may

differ from each other not only in factors for cultural characters but also for sex and pathogenicity.

6. Since the pathogenicity of individual biotypes derived from a single monosporidial line may differ, it is evident that chlamydospore collections or so-called physiologic forms of smut fungi may comprise a very large number of biotypes.

UNIVERSITY OF MINNESOTA

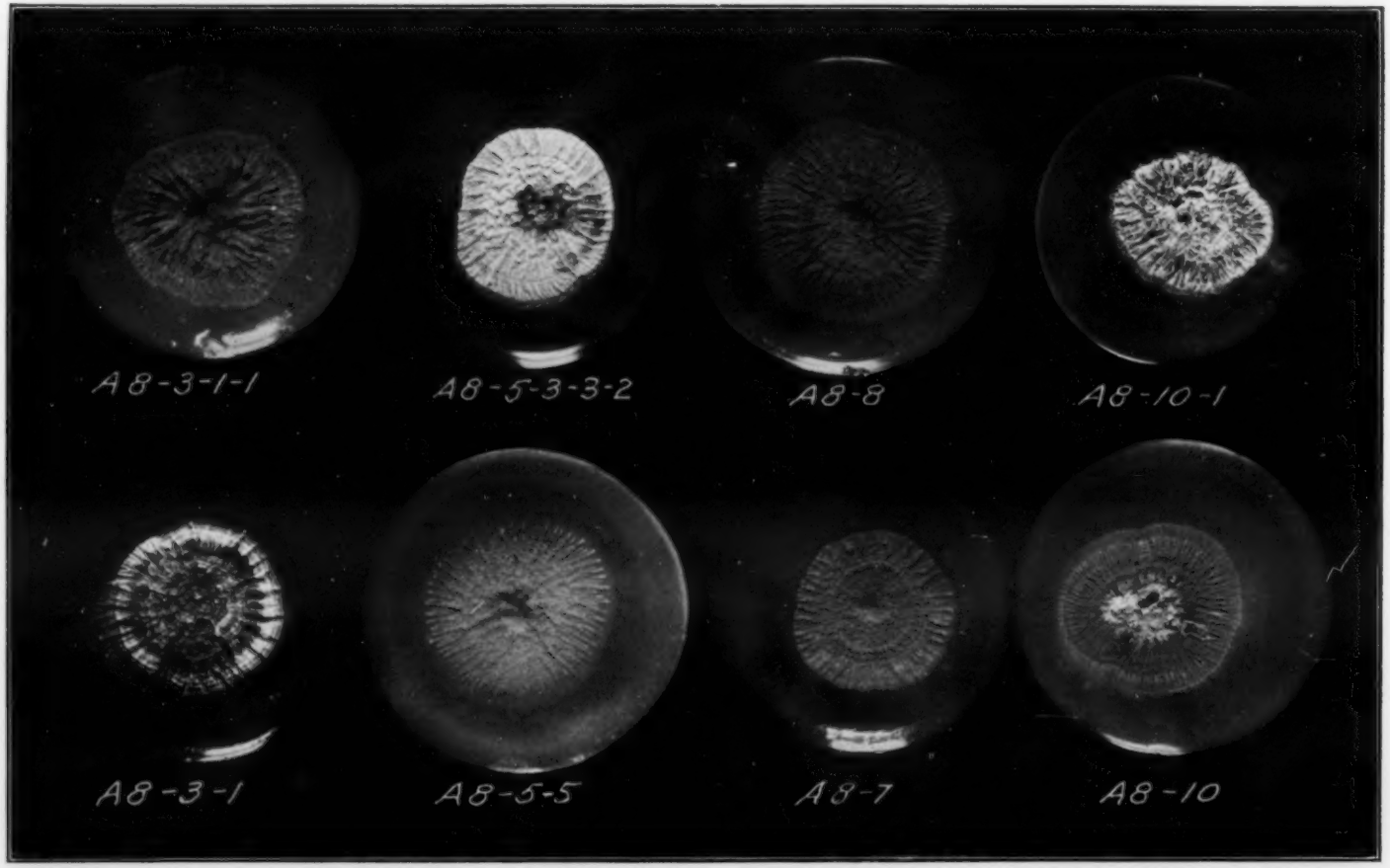
Explanation of plates

Plate 27

Eight variant derivatives of W. Va. A8. All have retained their distinctive cultural characters for 4½ or 5 years, except A8–10–1 and A8–3–1–1, which arose fairly recently as sectors in A8–10 and A8–3–1–1, respectively.

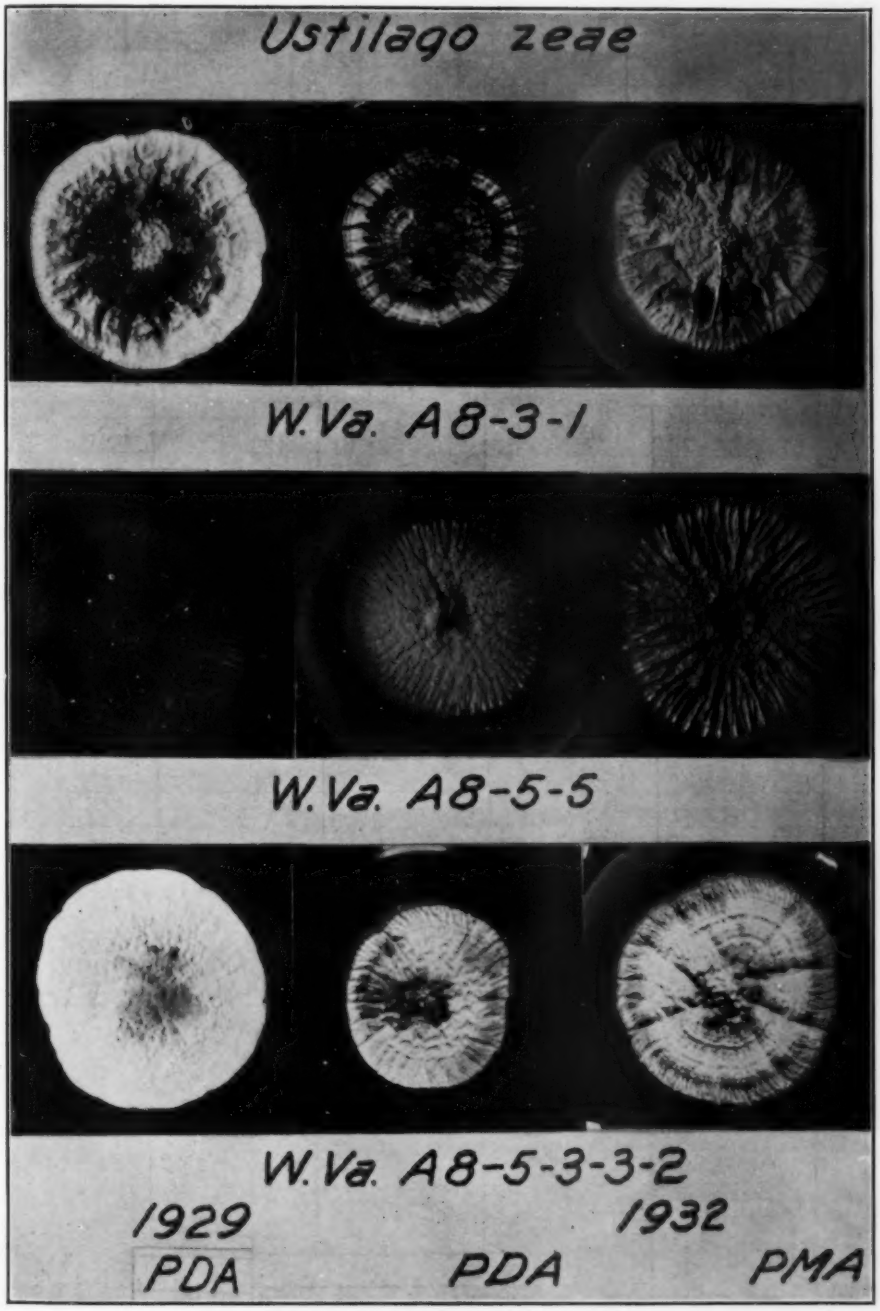
Plate 28

Three variant lines of the W. Va. A8 series. Left, colonies of the 3 lines on potato dextrose agar in 1929; middle, the same 3 lines on potato dextrose agar in 1932; right, on potato malt agar in 1932. This shows phenotypic variability but indicates genotypic stability, as the distinctive characters of each line are persistent.



UNIV. OF MICH.

STAKMAN, TYLER AND HAFSTAD: USTILAGO



STAKMAN, TYLER AND HAFSTAD: USTILAGO

UNIV. OF MICH.

The germination and growth of Peltandra virginica in the absence of oxygen[1]

THOMAS I. EDWARDS

(WITH TWO TEXT FIGURES)

Germination in the virtual absence of oxygen has been reported for *Alisma Plantago* by Crocker and Davis (1914) and by Schaumann (1926). The anaerobic germination of rice has been observed by a number of workers, including Nagai (1916) and Sasaki (1930). Similar reports have been made for the seeds of *Typha latifolia* and *Cynodon dactylon* by Morinaga (1926); for *Nelumbo nucifera* seeds by Ohga (1926), for *Trapa natans* by Teresawa (1927), and for *Euryale ferox* by Okada (1930). It is worth noting that all of these plants grow in, or close to, water, and that all but *Trapa natans* are monocotyledonous plants. Several methods have been used by these workers for removing oxygen from their cultures. These include displacement of air by an inert gas, usually nitrogen or hydrogen; absorption of oxygen in alkaline pyrogallol; and removal of atmospheric oxygen by the use of a suction pump. The last method provides the severest test because it removes the air from the spaces between the seed organs and to some extent from the intercellular spaces also.

In addition to these papers there are numerous reports of failures to secure germination of the seeds of the common crop plants in atmospheres of very low oxygen tension. These began to appear soon after the discovery of the air pump. Also, soon after the discovery of the commoner gases experimenters tested their effect on germination without finding any seeds that were capable of germination in the absence of oxygen. The only other group of papers requiring to be mentioned here is that reporting efforts to grow plants in rarified atmospheres. Representative of this type of work are the papers of Wieler (1883) and Nabokitch (1903). Their objective was to measure the elongation of plant organs of cultivated species at exceedingly low oxygen tensions. The weakness of these experiments is to be found in their failure to discriminate between mere elongation (the physical phenomenon of taking in water and expanding pre-formed cells) and growth in the stricter sense (including division of cells in a meristematic region, elongation, and maturation).

The present paper deals with the ability of the seeds of *Peltandra virginica* (L) Kunth., a member of the Araceae, to germinate in an atmosphere nearly, if not completely lacking oxygen, and to elongate their plumules from two to three times their original length under these conditions.

[1] From the Department of Biology of the School of Hygiene and Public Health The Johns Hopkins University, Baltimore, Maryland.

MATERIAL

The seeds of *Peltandra virginica* used in this study were collected from plants growing on a muddy bank or in shallow water just above the Great Falls of the Potomac River on the Maryland shore in October, 1932. This species grows in marshes throughout the eastern part of the United States. Its seeds are imbedded in a tenacious jelly and are surrounded by a tough pericarp. The seeds, which weigh about 0.8 gram each, on the average, consist of a large, well-developed and slightly curved embryo whose plumule is about 8 mm. long, lying in a groove along a large mass of starchy endosperm. The seeds needed only to be removed from the pericarp to be capable of germination and any injury to the pericarp or the attack of a fungus was enough to initiate germination. At the time of collection the seeds germinated slowly but after several months storage in the fruit coats at room temperature, and also in seeds freed from the coats and stored at 5°–8°, germination occurred in much less time. Usually the plumule was the first part of the embryo to emerge from the seed.

NUMBERS OF SEEDS PER FRUIT

Of 757 *Peltandra virginica* fruits examined, 719 contained only one seed, 34 two seeds, and 4 fruits contained three seeds. When plotted these data give rise to a so-called J-shaped distribution which falls off very steeply. The biometric constants for this distribution and their probable errors are as follows: average number of seeds per fruit $1.055 \pm .006$; standard deviation $.251 \pm .004$; coefficient of variation $23.8 \pm .4$. When more than one seed was found in a fruit the seeds were usually of about the same size but somewhat smaller than the seeds which occupied a whole fruit and were flattened where they touched each other. Only seeds from single-seeded fruits were used for these experiments although the others germinated in satisfactory manner.

Counts of this kind have been reported for the fruits of a number of species which reveal some differences in frequency distributions. For the bilocular and trilocular fruits of *Ptelea trifoliata* Harris (1911a) found distributions much like that of *Peltandra*. According to the same author (1912) *Crinum longifolium* and also (1911b) *Staphylea trifolia* and *Cladastris tinctoria* have larger numbers of seeds per fruit than *Peltandra* but they too bear one-seeded fruits more frequently than any other kind and their distributions of seed number may be represented by curves of this sort. In these sets of data Harris recorded the presence of small numbers of fruits containing no seeds and when this was represented graphically the curves became strongly skewed. No records were taken of the possible occurrence of such fruits in *Peltandra*.

More frequently, however, curves approaching the form of the normal Gaussian curve have been obtained. Pearson (1901) reported the seed frequencies of *Cytisus scoparius*, *Lotus corniculatus*, *Lathyrus odoratus*, *L. sylvestris*, *Vicia Faba*, *and V. hirsuta*, all but *Lotus* having fairly symmetrical distributions. Pearl (1906) described the numbers of seeds found in a collection of *Nelumbium luteum* fruits and calculated the descriptive constants of the distribution. Harris (1909) confirmed Pearson's findings for *Cytisus* and later (4) studied the distributions of *Sanguinaria canadensis* seeds in collections of fruits made in two seasons. Harris's (1916) data for *Cercis canadensis* fall on a very symmetrical curve. In most of these cases the mean number of seeds and the standard deviations are much greater than for *Peltandra* but the coefficients of variation, which show the relation of the standard deviation to the mean, are roughly of the same magnitude.

It is conceivable that many factors may influence the numbers of seeds that may ripen in the fruits of a given species, important among them being the number of ovules laid down during the development of the flower and the number of these that are fertilized. The seed counts made on *Peltandra* fruits are based on the number of seeds that reach maturity but probably many others attain only a fraction of their development. In these counts there has been no attempt to record the number of seeds that reached, for instance, only a fourth of their development before being crowded out or robbed of food by more vigorous seeds. If it were possible to estimate these partial stages of development in a quantitative manner it would be necessary to deal with fractional values in studying seed distributions, and the frequency curve would have to show classes between zero and one seed per fruit. In such a case the appearance of a J-shaped curve would be lost and instead one would have an extremely skewed frequency curve. There does not seem to be any reason at present for regarding these asymmetrical distribution curves as being radically different in kind from the nearly symmetrical distributions. It would seem that any attempt to interpret the biological significance of these curves must rest upon a closer study of the living plant throughout the growing season in order to note at what stages the development of individual ovules is arrested and to ascertain the causes of these failures. At present it is not possible to carry this study further on *Peltandra*. It is worth noting, however, that this tendency toward the production of one-seeded fruits does not seem to put the species at any conspicuous disadvantage to judge from the relatively wide geographical distribution it has on this continent. It is found growing in marshes as far south as Florida and Louisiana and as far north as Maine and Michigan.

METHODS

In order to decide upon a suitable temperature for carrying on these tests, measurements of the growth of 6 *Peltandra* seedlings in darkness were made at each of 6 constant temperatures. The seeds were laid on moist sand in tall, rectangular, glass jars which were kept covered. Growth was most rapid at 29° with the 25° cultures not far behind. The 35° seedlings were quite irregular in size, the best of them growing slightly slower than the 25° ones. At 20° growth was slower still; at 15° it was greatly delayed, and at 12° plumules did not develop during the month the cultures were kept under observation, although subsequently some growth did occur. A large number of seeds freed from the pericarps were stored at 5°–7° and in the course of six months many of them germinated and the plumules elongated a few millimeters. These seedlings lacked the normal geotropic response.

Soon after the seeds were collected preliminary tests showed that they were able to germinate and the plumules were capable of elongation if the seeds were submerged in water through which hydrogen from a simple generator was bubbled, and also when they were exposed over alkaline pyrogallol. The tests which best indicate their ability to germinate and to grow in exceedingly low oxygen tensions were made six months later after the seeds had been stored at 5°–7° in darkness, conditions under which germination goes on very slowly. Three *Peltandra* seeds were introduced into each of a number of soft glass vials, 2.5 cm. in diameter and about 15 cm. long. By manipulation in a flame a zone of glass about 11 cm. from the bottom was allowed to soften and to form a thick-walled tube, 1–2 mm. in diameter, the seeds being kept cool during this process. When the tube had cooled about 10 cc. of tap water were introduced into the part of the tube containing the seeds, the tube was connected to a water aspirator and the atmospheric pressure reduced until the water boiled at room temperature (about 23°C.). The evaporation of the water was often hastened by heating to about 30°. This procedure undoubtedly had the effect of washing out all but traces of the atmospheric gases left in the tube, to say the least, and also of removing the gases from the intercellular spaces of the seed. When nearly all of the water had been evaporated the tube was sealed off in a small flame without any interruption to the suction and as soon as the glass had cooled the culture tube was entirely submerged in water strongly colored with dye so that if any leakage occurred it would be evident on inspection of the seeds. Tubes so sealed, together with controls consisting of seeds in open tubes, were cultured in darkness at 24°, a temperature a little below the optimal temperature for growth, and after growth had ceased they were removed, measured, and photographed.

It should be noted that three factors contribute toward reducing the oxygen tension. (1). At the very first operation, gaseous pressure in the tube was reduced to about 20 mm. Hg, which removed the greater part of the oxygen originally present. (2). Approximately 10 cc. of water is evaporated at this pressure, which theoretically should occupy a volume of more than 500 liters when reduced to vapor at 23° and 20 mm. Hg, and the continued production of water vapor during suction would displace all but traces of oxygen from the culture tube. (3). The respiratory activity of the seeds themselves would be expected to use up oxygen, and since the cultures were in darkness no additions of oxygen as a result of photosynthesis could occur. If any gaseous oxygen can remain after this treatment its concentration must be exceedingly small.

RESULTS

Figure 1 is a photograph of treated seedlings and controls taken 9 days after the tube at the left had been sealed off in the manner just described. It is typical of five other experiments in which *Peltandra* seeds were sealed in tubes of this and other forms and into which no leakage occurred. This particular experiment was started with seeds whose plumules had just begun to elongate and in the almost complete absence of oxygen they grew to lengths of 3.0, 2.2, and 2.2 cm., or until in the presence of air the first foliage leaf would have broken through the coleoptile. Instead, however, no further development of the plumule occurred; the control seedlings in the tube at the right developed two foliage leaves in the same time and under the same conditions. Root development was almost completely suppressed in the absence of oxygen although it was vigorous in the control seedlings.

Even though *Peltandra* seedlings are cultured in darkness and are examined at infrequent intervals only in weak light the seedlings are greenish, even more so than the controls. Microscopic examination of the seeds stored at low temperature in darkness for six months shows an abundance of green chloroplastids throughout the embryonic plumule and in the first three layers of the endosperm. It appears that these merely persist in the seedlings grown in darkness, and that there is no reason to assume that chlorophyll formation takes place under these conditions. If this is so then the deeper green of the seedlings cultured anaerobically might be due to the circumstance that the surface area is smaller and the plastids are more concentrated on that account.

When the culture flasks were broken open at the end of an experiment there was no trace of any odor which might have been attributed to putrefaction; the seedlings normally have a peculiar but not unpleasant odor

when they are grown in air and nothing but this was apparent in the sealed tubes. The tips of other tubes were broken under dilute NaOH solution; at first the liquid filled about 1/3 of the tube, but in a short time almost all

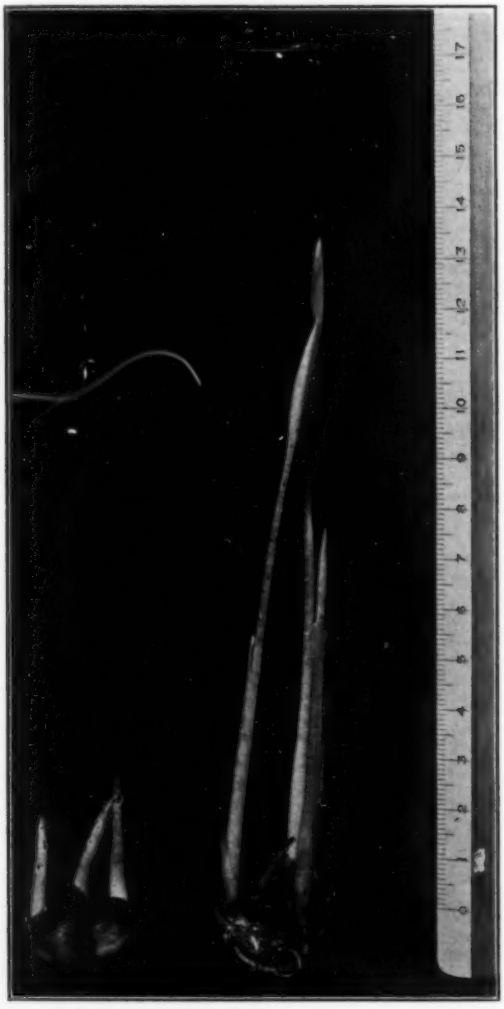


Fig. 1. *Peltandra virginica* seedlings nine days old. The ones at the left grew in the absence of oxygen; the controls at the right were grown in air.

of the gas was absorbed. This gives a rough indication of the high carbon dioxide tension prevailing in the sealed culture tubes. The small amount of gas remaining was not soluble in alkaline pyrogallol and as a gas analysis apparatus was not available its nature is unknown.

Seedlings which had ceased to grow under anaerobic conditions were fixed, sectioned, and stained for a comparison of their tissues with those of seed embryos and to permit an estimate of the likelihood of cell division under anaerobic conditions. The photomicrographs of Figure 2 were prepared from such sections and show the appearance of portions of the coleoptile and the first foliage leaf. The upper photograph is a median longitudinal section through a seed which had not begun to elongate and shows

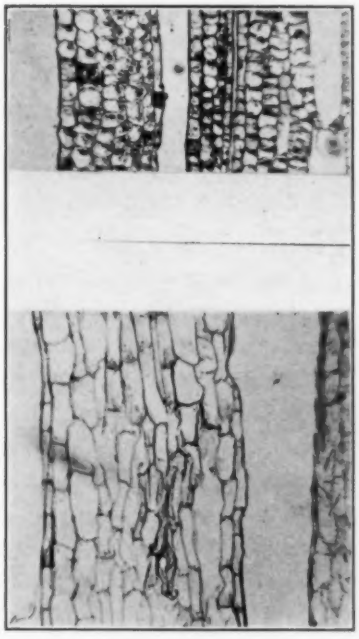


Fig. 2. Photomicrographs showing median longitudinal sections through the coleoptile and adjacent leaves of *Peltandra virginica*. Above, through the seed embryo. Below, through a seedling which had ceased to grow in the absence of oxygen. 56×.

cells that are approximately square. In the lower photograph prepared from a comparable section through one of the seedlings shown in Figure 1, and taken at the same magnification, the cells appear to be 2–4 times as long as they are broad. This section passes close to a vascular bundle. Since the cells elongate to these proportions, and since the whole organ increases in length only 2–3 times there would seem to be no need to suppose that any new cells were formed in order to account for the observed elongation, especially since there was only a slight increase in the thickness of the coleoptile. Moreover, in the coleoptile as it was observed in the seed there are no cells that have the appearance of meristematic tissue when com-

pared with the stem growing point. From these observations it would appear that the increase in length of the seedlings was due to the elongation of cells already formed in the embryo.

Three other kinds of seeds were tested in the same way as the *Peltandra* seeds, *viz.* rice, cress, and sunflower, the latter two failing to germinate. The longest rice coleoptile was 2 cm. in length and several others were nearly as long. Like the rice seeds cultured by Nagai (12) in the absence of oxygen, these rice seedlings did not develop roots. On the whole, the performance of rice seeds was essentially the same as that of *Peltandra*.

DISCUSSION

Perhaps the most striking feature of these experiments is the evidence they present of the unusual tolerance these plants must possess to the products of their own anaerobic respiration. Almost all plants so far studied have been able to carry on respiration for a time in the absence of oxygen, but it appears that they poison themselves with the accumulation of metabolic products which in the presence of oxygen are oxidized to relatively inactive substances, usually carbon dioxide and water. Either these *Peltandra* seedlings possess a type of respiratory metabolism that produces non-toxic intermediary products when complete oxidation is prevented, or if their metabolism is not greatly different from that of most other plants so far studied their tolerance to these metabolic products is far higher. There are not enough seeds of this lot left to permit an extensive study of this question at the present time.

It is a pleasure to acknowledge the advice and assistance of Professor Raymond Pearl during the preparation of this paper.

SUMMARY

The seeds of *Peltandra virginica* are able to germinate in the almost complete absence of oxygen and under these conditions the coleoptile may elongate two or three times its original length. This seems to be due entirely to the elongation of cells already formed in the embryo. Rice also germinates and develops to about the same stage as *Peltandra;* cress and sunflower do not.

Of 757 *Peltandra* fruits examined, 719 were one-seeded, 34 two-seeded, and 4 contained three seeds.

Preliminary tests showed the optimal temperature for seedling growth in air to be about 29°C.

Literature cited

Crocker, W., & W. E. Davis. 1914. Delayed germination in seed of *Alisma Plantago*. Bot. Gaz. **58:** 285–321.

Harris, J. A. 1909. Variation in the number of seeds per pod in the broom, *Cytisus scoparius*. Am. Nat. **43**: 350–355.

————. 1909. Correlation in the inflorescence of *Celastrus scandens*. Ann. Rpt. Missouri Bot. Gard. **20**: 116–122.

————. 1910. A quantitative study of the morphology of the bloodroot, *Sanguinaria canadensis*. Biometrika **7**: 305–351.

————. 1911. Seed weight in *Staphylea* and *Cladastris*. Torreya **11**: 165–169.

————. 1911. Teratological fruits of *Ptelea*. Bull. Torrey Club **38**: 385–387.

————. 1912. Biometric data on the inflorescence and fruit of *Crinum longifolium*. Ann. Rpt. Missouri Bot. Gard. **23**: 75–99.

————. 1913. On the calculation of intra-class and inter-class coefficients of correlation from class moments when the number of possible combinations is large. Biometrika **9**: 446–472.

————. 1916. A contribution to the problem of homotyposis. Data from the legume *Cercis canadensis*. Biometrika **11**: 201–214.

Morinaga, T. 1926. The favorable effect of reduced oxygen supply upon the germination of certain seeds. Am. Jour. Bot. **13**: 159–166.

Nabokitch, A. J. 1903. Zur Physiologie des anaeroben Wachstums der höheren Pflanzen. Beih. Bot. Centralbl. **13**: 272–332.

Nagai, I. 1916. Some studies on the germination of the seed of *Oryza sativa*. Jour. Agr. Coll. Tokyo Imp. Univ. **3**: 109–158.

Ohga, I. 1926. The germination of century-old and recently harvested Indian lotus fruits, with special reference to the effect of oxygen supply. Am. Jour. Bot. **13**: 754–759.

Okada, Y. 1930. Study of *Euryale ferox* Salisb. V. On some features in the physiology of the seed with special respect to the problem of the delayed germination. Sci. Rpts. Tohoku Imp. Univ. IV, **5**: 41–116.

Pearl, R. 1906. Variation in the number of seeds of the lotus. Am. Nat. **40**: 757–768.

Pearson, K., et al. 1901. Mathematical contributions to the theory of evolution. IX. On the principle of homotyposis and its relation to heredity, to the variability of the individual, and to that of the race. Part I. Homotyposis in the vegetable kingdom. Phil. Trans. Roy. Soc. London. A **197**: 285–379.

Sasaki, T. 1927. On an abnormal type of germination of rice seeds under reduced air supply. Jour. Sci. Agr. Soc. 288: 101–102. (See Biol. Abstracts **4**: 3848. 1930).

Schaumann K. 1926. Über die Keimungsbedingungen von *Alisma Plantago* und anderen Wasserpflanzen. Jahrb. Wiss. Bot. **65**: 851–934.

Terasawa, Y. 1927. Experimentelle Studien über die Keimung der Samen von *Trapa natans*. Bot. Mag. Tokyo **41**: 581–588. (See Biol. Abstracts **3**: 11641. 1927.)

Wieler, A. 1883. Die Beeinflussung des Wachsens durch verminderte Partiärpressung des Sauerstoffs. Unters. Bot. Inst. Tübingen **1**: 189–232.

On the vaccination of the tobacco plant against Thielaviopsis basicola

CARLO ARNAUDI[1]

(WITH FOUR TEXT FIGURES)

Until a few years ago, vegetable immunology was essentially natural immunology, and the study of natural susceptibility and resistance to disease held the field. The differences in resistance of certain species to given diseases were considered to be due only to environmental conditions, such as climate and nutrition, or to inherited characteristics.

It was shown some thirty years ago by Beauverie (1901) that plants could acquire active immunity by a process analogous to that of vaccination in animals, and in the same year other and equally positive tests were reported by Ray (1901). This line of work, however, was not followed up for more than twenty years, except by Bernard (1911), Magrou (1921) and Hiltner and Stoermer (1923), and they were concerned with resistance to super-infection rather than vaccination.

The then current ideas on the pathogenesis of plant diseases did not recognize the probability of the occurrence of immunological reactions of the animal type in the vegetable organism. On the contrary, the theories used to explain the phenomena of animal immunology emphasized those humoral reactions which one can hardly think of in connection with plants, and took too little into account the cellular defense which is evident even in plants. Thus an obstacle arose to the institution of parallels between the two kingdoms, particularly for those botanists who kept in view those organistic and autonomic cellular characteristics of plants that undoubtedly are among those most sharply separating plants from animals.[2]

This mental attitude of the vast majority of phytopathologists not only created conditions unfavorable to the development of modern immunological ideas, but led the research workers to overlook those cases of

[1] Istituto Sieroterapico Milanese. Agrarian and Industrial Bacteriological Section directed by Prof. D. Carbone.

[2] It is curious to note how almost as if to substantiate their opinions, some of those workers who denied the possibility of vaccinating plants, granted to animal vaccination a range which it actually does not possess. In fact, the number of infectious diseases in animals and in man in which vaccine therapy is clearly efficacious is not great. Even in the few most favorable cases 100% of success is never obtained. Effective vaccination is extremely variable and often of brief duration, and direct relations between circulating antibodies and immunity rarely exist. Nevertheless, the service that vaccine therapy has rendered and still renders in the struggle against infectious diseases in man and beast, is of the highest importance, and its introduction constitutes one of the greatest conquests of modern medicine.

naturally increased resistance in plants or their organs which might have been explained as cases of natural vaccination. Consequently, many individual phytopathological phenomena were disregarded which, had they been collected, studied, and compared, might have increased our knowledge of the genesis of plant diseases. Montemartini (1931) has recently examined both old and new works written with purposes and concepts far removed from those of our studies and has drawn from them deductions of the greatest interest.

The question of acquired immunity in plants was again taken up by Carbone (1919), who in a series of critical studies placed the problem of plant immunity in the picture of general immunity. He distinguished and marked the limits of the tasks of the two fundamental groups of research workers in our field: those who study the active artificial immunization of plants, and those more strictly theoretical investigators who study the production of vegetable antibodies and their presence in the cellular and circulating juices.

Next we have the notable experimental contribution by Zoja (1924), who immunized wheat against *Helminthosporium sativum*. Arnaudi (1925), in turn, vaccinated potato tubers against a *Bacillus* of the *B. mesentericus* group. And Hursh (1925) showed that a treatment of the stalks and leaves of wheat, cabbage, cauliflower and other plants with sterile filtrates of *Leptospaeria herpotrichoides*, *Fusarium vasinfectum* and *F. oxysporium* fortified them against a second and more powerful treatment with the same filtrates.

In 1926 appeared the report of the researches by Sieden and Trieschmann, who immunized potato tubers against "cancer," and in 1927 that by Benigni who immunized small maize plants against *Ustilago Maidis*. Arnaudi in 1928 again returned to this subject. By vaccinating small pea plants against *Blepharospora cambivora*, he demonstrated the specificity of the vaccination by treatment and cross-infection with other micro-organisms. In the same year Nobecourt reported vaccination of beans against *Botrytis cinerea* and *B. carotovorus*.

In 1930, Carbone and Arnaudi collected in a single monograph all that had been done in the field of acquired immunology in plants and coordinated the experimental facts which had been ascertained up to that time both by themselves and by other workers. They also elaborated a plan for future research.

In the following years, besides a noteworthy group of studies on plant antibodies by Kostoff (1929), Silberschmidt (1931) and Chester (1932) a few experimental contributions in the field of vaccination served to clear up certain details of its mechanism. Jarach (1932) discussed the proposi-

tion, put forward by some, that the plants supposed to be vaccinated were really rendered unsuitable for the development of the infectious organisms by impregnation with microbicidal substances in the vaccinating liquid.[3] Working on the couple, dwarf bean and Toile [*Botrytis cinerea*], he showed that the phenomenon was due to reaction by the plant to the effect of the vaccine. Using a technique that does not alter the vaccine, he found that the pathogenic micro-organisms grew perfectly on a plant first vaccinated and then killed. Carbone and Kalaiew (1932) have continued the work on the mechanism of vaccination and have shown that the vaccine can not be precipitated by alcohol and that there is no parallel between the toxicity and the immunizing power of a vaccine. Using various chemicals and physical agents, they also produced degrees of injury in order to discover whether any particular state induced a higher degree of resistance to the pathogenic agent. They concluded that the vaccine exerted a specific action upon the protoplasm of the affected cells.[4]

At about the same time Leemann (1932) published his notes upon the natural influence of pathogenic or non-pathogenic micro-organisms of the soil on the receptivity and resistance of plants; he also described his experiments on the immunization of wheat against *Helminthosporium sativum*.

A few workers, in the meantime, invoked naturally acquired active immunity to explain cases of greater resistance, which certain plants showed against various parasites. Montemartini (1930) supposed that the progressively increased resistance to *Oidium*, which is shown by the oak, is due to slow natural immunization, and he supports this view with experimental evidence. East (1931) came to an analogous conclusion in the case of the mosaic disease of the sugar cane. East (1930–31) also placed in high relief the possibility of an important connection between the views of modern vegetable immunology and experimental genetics. According to him, those varieties of sugar cane that show greater resistance to the mossaic disease have undergone a progressive process of vaccination, which is recognizable by precipitation reactions on the juices. The plants that had

[3] This phenomenon has been described repeatedly with experimental evidence. Potter (1909) described an experiment in which he inoculated the culture-liquid filtrate of a *Penicillium* into the fruit of the orange; he noted that the *Penicillium* no longer grew in these fruits while it continued to develop on other untreated ones. He supposed that the metabolic products of the fungus protected the plant, but it is not impossible that even in this case actual immunization took place.

[4] In connection with the mechanism of vaccination, I may mention some unpublished experiments of my own upon the bean, using the Toile as the agent. I wished to note the effect of repeated vaccinations, using constant or variable quantities of vaccine. The results were uniformly unfavorable. In fact, there was sometimes a slightly higher degree of sensitiveness in the plants treated than in the controls.

overcome the disease react to the precipitation test like those that, apparently healthy, acted as carriers, while those which have never suffered from the disease in any degree differ profoundly in their reaction to the test.

The most recent contribution to our problem is that of Gheorghiu (1932), who has introduced into vegetable vaccine therapy the concept of local immunity and using a technique inspired by that idea and vaccinated plants of *Pelargonium* against *Bacterium tumefaciens*. Arnaudi (1928) had already demonstrated the resistance to superinfection by *B. tumefaciens* shown by *Pelargonium* having tumours, when the new inoculation is made rather close to the primitive tumour. Now Gheorghiu so planned his experiments as to bring out the local action of the vaccine, and the corresponding cellular reaction of the tissues showed that increased resistance to the primary infection could be obtained.

In the works here briefly summarized, we have confirmation of the conclusions, reached by Carbone and Arnaudi in their monograph, that the natural resistance of phanerogams to the infectious action of cryptogams[5] may be increased when the former have undergone and overcome a first attack of the disease, or when they have absorbed killed germs or materials derived from the infectious germs themselves.

In the works mentioned above the operative treatment has been given in detail in order to emphasize the conditions which are most favorable for the observation of increased resistance to parasites and for the study of the mechanics of the reactions. These investigations have been exclusively theoretical in character. In the experiments described in this article a first attempt is made to vaccinate plants as an agricultural technique. We have not yet set up rules for a general application of vegetable vaccine therapy, but our laboratory experiments have been carried out with this in view.

In the monograph of Carbone and Arnaudi (1930) we foresaw practical applications of vegetable vaccine therapy as follows: (1) An indirect application through the experimental production of species and varieties in which natural resistance to parasites is reinforced.[6] (2) A direct application by which valuable plants—particularly those which are raised from seed—are treated and then transplanted.

[5] Heinricher (1929) has demonstrated that the pear increases its resistance to the mistletoe following a first attack by that parasite. This leads one to think that the phanerogams have a possibility of acquiring resistance to higher forms of parasites also.

[6] The research work in this direction, being necessarily extremely laborious and calling for the use of a large number of plants, should be facilitated by the method of iarovisation devised by T. D. Lyssenko. This method allows the vegetative cycle of the plants to be shortened materially.

We therefore chose the tobacco plant as desirable material. Among the diseases of the tobacco plant, as an etiological agent that can be cultivated artificially—which is a fundamental condition if the preparation of the vaccine is to be easy, we chose *Thielaviopsis basicola*. It seemed to us that this agent was the most suitable for our purposes because of its wide diffusion in nature and because of the serious damages which it causes every year in tobacco plantations. On the other hand, *Thielaviopsis basicola*, as is well known, does not cause disease of an acute character, its toxic action being low; the infection manifests itself rather slowly; the attack

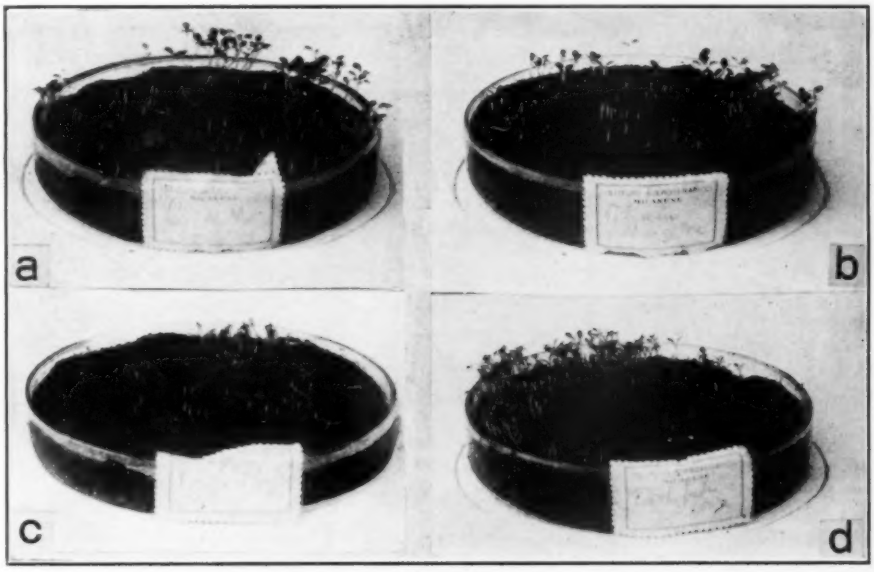


Fig. 1. Tobacco plants treated with *Thielaviopsis basicola* and *Pythium* vaccine. Note the various pathological symptoms caused by *Thielaviopsis* vaccine ether (c), *Thielaviopsis* vaccine heat (d), and *Pythium* vaccine heat (b), as compared with the control plants (a).

on the roots and the "collar" of the seedlings takes place without producing manifest symptoms of suffering. It is only when the infections continue that the plant becomes backward in development, so that at the ordinary time of transplantation, if the infection is great in the seed bed, it will be found that a lesion has developed which has cut off the stem from the root. These characteristics are such as to make experimental attempts at vaccination more difficult and to disturb estimates of the intensity of infection. For similar reasons the characteristics are not the most suitable for a study of the technique of preparation, administration, and effect of vaccinating materials. We were therefore forced to multiply the tests and to repeat the

same experiment many times in order to avoid erroneous interpretations of the results. Hence the research work was prolonged until the end of the summer of 1932. The entire experiments were carried out on the Berkley variety, with seed of 1930, which Dr. M. Donadoni, Director of the Angeloni Experimental Institute for Tobacco Culture at Scafati, was kind enough to furnish us and to whom I renew my sincere thanks.

The first vaccination tests were carried out with the technique and concept of the problem as a purely theoretical one, in order to collect the greatest possible number of observations from which to draw deductions applicable to practical work in vaccination. The tests were numerous, as I have already mentioned, but, for the sake of brevity, I will cite only a few of them here.

ORIENTATION TESTS

During the orientation tests lots of forty plants were used in each experiment. The seed was germinated in Petri dishes filled with sterile sand. When they showed the first signs of germination, small quantities of vaccinating material were poured on (about 2 cc. for each plate of 6 cm. in diameter). These tests were for the purpose of establishing the most suitable moment for administering the vaccine and for indicating to us the most favorable technique for preparation of the vaccine itself. Since the extreme delicacy of the plants makes it wise to disturb them as little as possible, the vaccinating material was administered as a fluid, in such a manner that it could be absorbed little by little into the sand and thus be carried to the root tips.

In all the vaccinations there was a first phase, immediately following application, during which the plants showed more or less intense signs of disturbance. These symptoms were of great variety and might be such specific traits as yellowing of the leaves, or browning of the root ends, or a more general symptom noticeable as retardation in development. These signs of suffering were not intimately correlated with intensity of the vaccine, as Carbone and Kalajev (1932) have shown, and as we shall show, later. One must regard the appearance of these signs as characteristic of the treatment and also, one might almost say, a proof of the activity of the vaccine material.

During these orientations four forms of vaccine were used, two based on cultures of *Thielaviopsis basicola*, and two based on cultures of *Pythium*. One vaccine in each pair was prepared by killing with ether, the other by killing with heat, in order to determine the conditions under which signs of disturbance in the tobacco plants were most evident.

These conditions were realized by administering the vaccinating liquid eight days after the seed had been planted (kept at 24°C.), that is to say,

at the moment at which the seeds were showing the maximum swelling or had commenced to sprout. The signs of suffering appeared after eight days and became more marked towards the twelfth day. The entire treated populations showed much more suffering than the controls, development in certain of the plants being only one-half of that exhibited by the controls (see figs. 1 and 2). Although the leaves did not show any particular characteristics of disease beyond a difference in degree of development and in number, the roots were more or less strongly tinged with brown, and in the lots treated with ether vaccine the epidermis showed lesions. In making a microscopic examination it was noticed that the epithelial tissues had become brown and slightly shrunken. These characteristics were com-

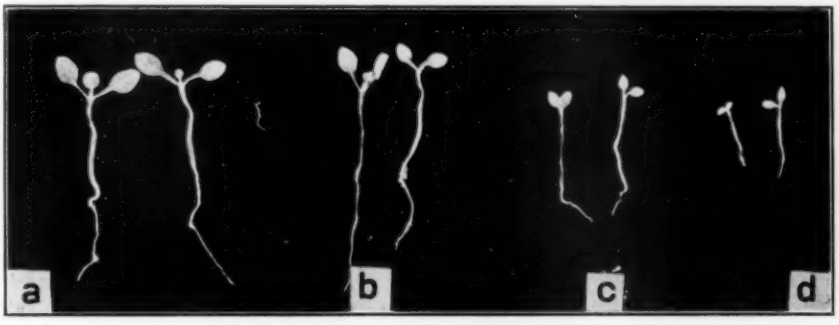


Fig. 2. Demonstration of the pathological symptoms caused by the various vaccines tested: (a) control; (b) *Pythium* vaccine; (c) *Thielaviopsis* vaccine (heat); (d) *Thielaviopsis* vaccine (ether). The photograph does not show the differences in color exhibited by the roots because it was taken on samples which had been kept in fixing liquid for some time, thus causing discoloration of the subjects.

mon to all the plants treated and appeared with greater intensity in the plants treated with ether vaccine of *Thielaviopsis basicola*, whereas they were extremely rare in the case of plants treated with *Pythium* vaccine, either of the ether-killed or of the heat-killed types (see fig. 2).

On the fifteenth day the plants were transplanted from the Petri dishes into ordinary flower pots containing sand. The manipulation was carried out by transferring small blocks of sand, in which the plants were fixed from the plates by means of a spatula, and depositing them cautiously in the prepared flower pots. Under these conditions the plants regained strength in a few days' time. Twenty days later their appearance was in no way different from that of the controls (see fig. 3 above). At this moment infection was produced by pouring into each flower pot a watery suspension extremely rich in Thielaviopsis. The flower pots were then transferred into the hothouse. The growth of the infecting agent was very weak,

probably owing to the fact that the earth in the flower pots was mixed with sand and constituted an unfavorable condition for the parasite. Clearly, a general infection was not obtained; nevertheless the results were positive. An examination made twenty days after the date of infection showed that while the general development of the plants was almost the same in all the lots, the number of the individuals was smaller in the controls and in the flower pots containing the plants treated with *Pythium*.

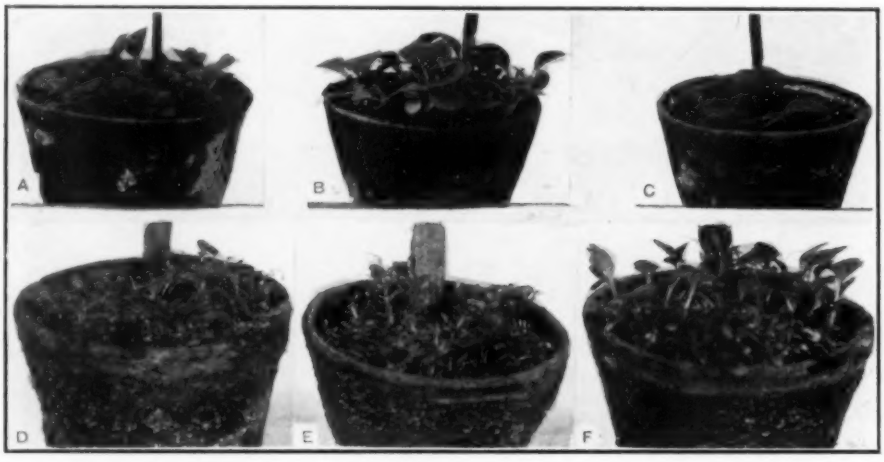


Fig. 3, above. The lots (a) heat *Thielaviopsis* vaccine, (b) *Pythium*, and (c) control shown in figs. 1 and 2, thirty days after transplanting. Fig. 3, below. Lots of tobacco plants vaccinated with (e) ether *Thielaviopsis* vaccine, (f) heat *Thielaviopsis* vaccine at fourteen days after the experimental infection, as compared with (d) the control plants which were similarly infected.

SECOND SERIES OF EXPERIMENTS

During the second series of experiments the seeds were planted directly in the flower pots. At the first signs of germination, one group of pots was treated with the ether vaccine, a second with the heat vaccine, while a third group was kept as a control. The amount of vaccine used was 5 cc. of suspension for each pot of 10 cm. in diameter containing forty plants. At the moment of vaccination the drainage holes in the pots were closed, in order that the vaccinating material should not be carried away when the plants were watered. The pots were kept in the laboratory under a large glass bell jar, the better to regulate the temperature and the humidity. After ten days the first signs of suffering were observed. This time—besides the symptoms already noted in the orientation tests—it was found that the leaves were less green and were slightly smaller. These symptoms were particularly evident in the plants treated with ether vaccine. The plants

which were treated with the heat vaccine were only slightly less well developed than the control plants. Instead, the roots showed lesions similar to those already described. The seals were now removed from the drainage holes in the pots, and the plants were watered rather freely, in order to carry away the traces of the vaccines. Six days later, when all the plants had again acquired a similar and normal appearance, infection was made with a suspension of Thielaviopsis. To favor the growth of the infecting agent and to keep all the pots in a warm, humid environment, part of the plants were placed in the hothouse and part under glass bell jars in the laboratory. The plants were watered with a suspension of horse manure, decanted and filtered, to which 0.5 parts per thousand of ammonium nitrate were added, in order to favor life conditions of the parasite.

Four days from the date of infection, the first yellow leaves began to appear in a pot belonging to the control group (under a bell jar); and four days later, almost half of the controls showed yellow colored leaves, whereas the plants of the vaccinated groups were normal. After ten days the vaccinated plants, also, began to show signs of distress. After a further period of seven days, the whole of the population of the control plants was dead, while from those treated with heat vaccine six plants survived, and from those treated with ether vaccine two plants survived.

The parallel series kept in the hothouse found better conditions for the plants and less favorable ones for the parasite. Fourteen days after the date of infection, differences were observed between the control, ether vaccine and heat vaccine lots (see Fig. 3, below).

Thirty-two days after the infection, there were small, yellowish, and less numerous plants in the control lots than in the vaccinated lots. Of the latter, the ether vaccine group was the least resistant to infection. The plants, although more numerous and vigorous than those of the controls, were however clearly more backward in development and smaller than those treated with heat vaccine, which were, on the average, much higher (even double) than those of the control group.

APPLICATION TYPE OF VACCINATION

Experiment 1. In view of the positive results obtained during the series of experiments of which, for the sake of brevity, only the modality of two groups has been described, we proceeded with vaccinations in the soil, using vaccines in powder form. In the paragraphs on technique, the procedure followed will be described minutely. For the moment we will call them Dry Vaccine No and Dry Vaccine E. In both cases the vaccination was given in the soil in which the seeds were planted. The experiments were made in the usual way in flower pots of 12 cm. in diameter. Use was made

of normal garden soil sterilized in the dry stove for four hours at 160–170°C. After having filled the pots with soil, and having pressed it down uniformly in order to obtain a regular and smooth surface, the vaccinating powder, mixed with a small quantity of fine soil, was sprinkled on in the desired quantity. This was done in order to obtain a more perfect distribution of the vaccinating powder on the surface of the soil in the pot. After having again lightly pressed down the earth to make the added powder adhere properly, forty seeds per pot were planted. Watering was effected by imbibition so as not to alter the stratification of the vaccine on the soil.

The quantities of vaccine used were:

1) control pot
2) 0.025 grams of Dry Vaccine No
3) 0.100 " " " " "
4) 0.200 " " " " "
(this was destroyed through an accident)
5) 0.500 grams of Dry Vaccine No
6) control pot
7) 0.025 grams of Dry Vaccine E
8) 0.500 " " " " "
9) 0.100 " " " " "
10) 0.200 " " " " "

The pots were left for three days at 30°C. and then, as soon as the seeds began to germinate, were taken into the hothouse and kept at 18–20°C. The vaccinated seedlings showed some signs of suffering, but not to the degree noted in the previous experiments, although the treatment was prolonged for a much greater length of time. Excluding the plants in pot No. 5, for which the dose of vaccine was evidently too high and which were backward in development to the end of the experiment, the others, even as they showed symptoms of disease very slowly, were equally slow in showing signs of recovery. In fact, the experimental infection, made in the same way as in the previously described tests, was effected about two months after the seeds had germinated. The conditions of the plants at seventeen days from the date of infection are shown in figure 4. After a further period of fifteen days, pot No. 1 still had three dying plants, while in the pots numbered 2 and 3 the plants were healthy and vigorous in appearance; but the difference in development between them was slightly decreased, since in No. 5 there were still about fifteen small and suffering plants having a development of about one-third of those in No. 2. The plants in pots 6 and 7 were all dead, while those in pots 8, 9, and 10 were about equal in development, and were healthy and vigorous. These plants, in fact, continued to develop like those in pots 2 and 3 until they had to be destroyed, owing to lack of space.

Experiment 2. The dry vaccines were again used in this test (i.e., No and E); but the method of administration was modified in that, instead of adding the vaccines to the soil with the seeds, they were pulverised (after having mixed them with fine earth) over the already germinated seeds. For each of the pots of 10 cm. in diameter and for every forty seeds, 0.100 grams of powder were used for both vaccines. As controls, three equal-sized pots of 40 non-treated seeds and two pots of 40 seeds vaccinated with 3 cc. of aqueous suspension of heat Thielaviopsis vaccine and ether Thielaviopsis vaccine, respectively, were used.

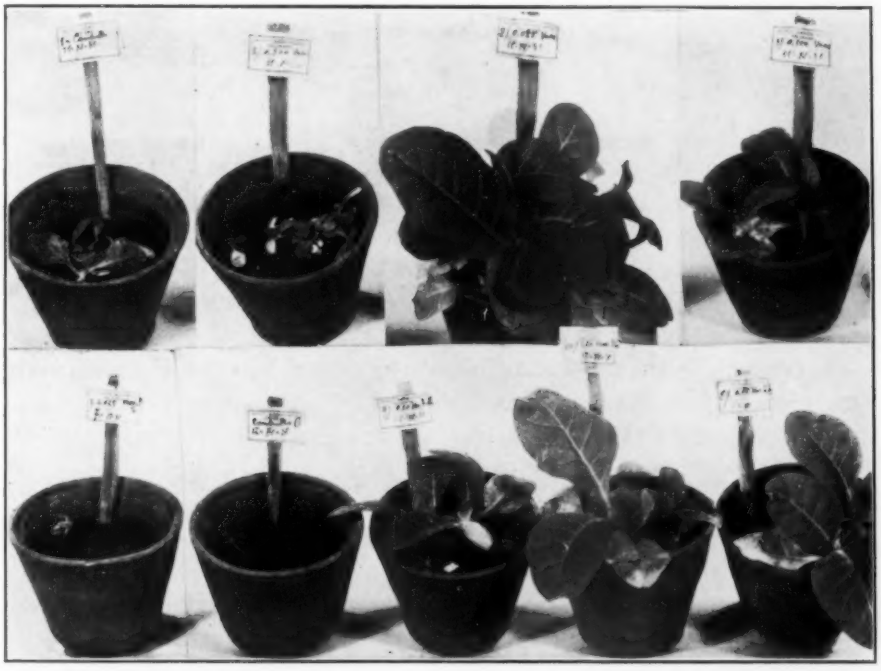


Fig. 4, above. Vaccination with *Dry Vaccine No*—State of the plants 17 days after the infection. The cards above the pots show the various quantities of vaccine used. Fig. 4, below. Vaccination with *Dry Vaccine E.* State of the plants 17 days after the infection. The cards above the pots show the various quantities of vaccine used.

For this series, also, the signs of suffering were but slight, especially in the case of the plants treated with aqueous vaccines. About two months after the vaccination, we proceeded to infect all the pots, following the usual procedure. Thirty-four days later, observations were taken. In the three control pots all the plants were small, rachitic, and chlorotic. On extirpating some, it was noticed that the typical lesions of the collar were present. The plants treated with aqueous vaccines, both of the heat and

of the ether type, were slightly healthier. The most vigorous plants, well developed and healthy, were those treated with Dry Vaccine E; those treated with Dry Vaccine No were slightly inferior in appearance.

Experiment 3. About sixty days after the preparation of the dry vaccines, we made another experiment, using forty plants for each procedure, following the usual technique, and making use of the usual pots. This experiment was for the purpose of testing the state of preservation and activity of the two preparations, which, in the meantime, had been kept in test tubes closed with cotton wool and left on the laboratory bench and therefore in full light. These tests, accompanied by the usual controls, also gave results wholly similar to the previous ones.

TECHNIQUE OF THE PREPARATION OF THE VACCINES

The preparation of the vaccines was carried out, with different techniques, by treating cultures of *Thielaviopsis basicola*. For this purpose the cultures were prepared in large test tubes containing malt broth,[7] or in flasks of 25 cm. in diameter in those cases where greater quantities of culture were needed. The incubation temperature was that of the laboratory in all cases (18–25°C.). The most suitable age for using the cultures was found to be from ten to fifteen days.

Heat vaccine was prepared as follows: a cultural felt obtained from a culture in malt broth, is pounded in a porcelain mortar with the addition of a little quartz sand (which is afterwards eliminated by decantation) until it is reduced to a creamlike consistency. It is then suspended in an equal part of sterile distilled water. The suspension is then placed for 30 minutes in a water bath, and kept at 70°C., as shown by a thermometer placed in the test tube containing the suspension. Before using this supension, it is diluted with an equal part of distilled water, shaking carefully both before dilution and before use so as to render it as homogeneous as possible.

Ether vaccine is prepared by careful trituration of the cultural felt of *Thielaviopsis basicola*, as in the case of the preparation of heat vaccine, but without water. The whole is then subjected to the action of ether vapor by placing the material in a thin stratum in a capsule which is kept under a well closed bell jar in which another wide-mouthed vessel containing ethylic ether is placed. Forty-eight hours afterwards, the material thus etherized

[7] In order to obtain abundant cultures in the large test tubes with ease, it is advisable to allow a streak of agar malt to solidify along the walls of the test tube. The piece of mycelium which serves for planting is placed on this streak. It develops on the agar and thence extends to the surface of the broth. If this expedient is not used, the piece of mycelium easily falls to the bottom of the test tube, and the cultivation of the mould is far more laborious.

becomes more fluid,—evidently by reason of the plasmolizing action of the ether on the mycelium of the microörganism. The only remaining operation is to drive off the whole of the ether which has become fixed. This is done by prolonged heating on the water bath at 37–40°C., followed by evaporation *in vacuo* at room temperature. When the whole of the ether is driven off, the material is diluted with three parts of water (distilled and sterilized), thus obtaining a concentration of mycelium produce equal to that of the heat vaccine.

Dry Vaccine No was prepared from normally cultivated cultures of *Thielaviopsis basicola* finely powdered in a mortar. The material thus obtained was spread in an extremely fine layer on a glass slip which was then heated to 37°C. in the thermostat. In less than 24 hours, the material was perfectly exsiccated. It was then collected with a spatula and left for a further 24 hours at 37°C. Under these conditions, the microörganism is killed, as was proved by cultural tests. For use, the material may be diluted with inert powders, such as fine earth, fine sand, powdered pumice, etc., which it is best to sterilize.

Dry Vaccine E was obtained by triturating the mycelium of *Thielaviopsis basicola* and treating the same with ether, following the same procedure as indicated for the ether vaccine, but without addition of water. The whole is then dried according to the same technique used for the Dry Vaccine No.

RESULTS AND CONCLUSIONS

From these experiments one may conclude that it is possible to increase the resistance of tobacco plants (variety Berkley) against infections by *Thielaviopsis basicola* by treatment with vaccines. The material used as vaccinating substance is obtained from cultures of *Thielaviopsis basicola* and may be prepared by following various procedures. Among these vaccines the type killed with ether and placed in aqueous suspension appears to be the most toxic, although it is the least active in conferring immunity. It is not to be thought that the greater toxicity shown by the ether vaccine is due to traces of ether which have remained attached to the vaccine, because the *Pythium* vaccine, prepared in an exactly similar manner does not produce detectable symptoms of suffering in the plants. The independence of toxic power and of immunizing power in the vaccines is therefore confirmed.

The types of vaccines which have given the best are certain powdered forms. These types have conserved and maintained their activity for two months without special precautions. (They were not examined after a greater length of time.) Of the powdered forms, those obtained by treatment with ether did not have the toxic power shown by the aqueous form,

yet they appeared to exercise an immunizing activity slightly superior to the normal.

The dry vaccines acted equally well whether added to the soil on which the germinating seeds were placed, or administered to seeds already germinated. This fact is in direct contrast to what was observed in the case of the aqueous vaccines, which appear to be less active when added directly to the soil.

The duration, under our experimental conditions, of the state of immunity acquired appears to be about two months. This point of the problem, however, is not clearly determined by our experiments. In order to obtain critical data, it would be necessary to observe numerous lots of plants, treated in various ways, infected at different times, and kept under the best conditions of life as regards surroundings and season. We are convinced, however, that the duration of the immunization obtained under our experimental conditions is sufficient to protect the plants during the early stages of life, which are the stages most freely exposed to the attack of the parasite and during which the plant exhibits the greatest degree of susceptibility.

As a general deduction, it is thought that the theoretical problems involved in the practical vaccination of tobacco plants against *Thielaviopsis basicola* are now sufficiently well in hand that it is desirable to make similar tests on a large scale in practical field cultures. When one considers the minute size of tobacco seeds (100,000 seeds weigh about 6 grams), it is clear that extremely small quantities of vaccinating material are sufficient to affect a large number of plants. Moreover, the preparation of the vaccine calls for a very simple technique whereby it is possible to prepare noteworthy quantities without excessive expense.

We close these notes by advising the reader that our Laboratory can place at the disposal of interested Institutes and private research workers, a certain quantity of vaccine in powdered form which we shall be glad to forward to those who may make request.

Literature cited

Arnaudi, C. 1925. Sulla immunità acquisita nei vegetali. Atti. Soc. Ital. Sc. Nat. **64.**

————. 1928. Nuove esperienze sulla vaccinazione delle piante. Riv. di Pat. Veg. **18.**

Beauverie, F. 1901. Essais d'immunization des végétaux contre les maladies cryptogamiques. C. R. de l'Acad. des Sci. 133: 107.

Benigni, E. 1927. Note sull' *Ustilago Maidis*. Riv. di Pat. Veg. **17,** Nos. 3 and 4.

Bernard, N. 1911. Sur la fonction fungicide, etc. Ann. Soc. Sc. Nat. et Bot. 9. Ser. 14: 221–234.

Carbone, D. 1919. Quarella & Venturelli Microbi saprofiti e microbi patogeni. Riv. di Biol. **1**: Fasc. 2, 3, and 4.

————. 1922. Studi sulle reazioni immunitarie delle piante. Bioch. e Ter. Sper. **2**: 261–265.

————. 1923. Le reazione immunitarie delle piante. Bioch. e Ter. Sper. **10**: 257–270.

———— **and Arnaudi, C.** 1930. L'immunità nelle piante. Monograph of the Milan Serological Institute, Milan.

———— **and Kalajev.** 1932. Ricerche sulla vaccinazione delle piante. Phytopathologische Zeitschrift **5**: Heft 1.

Chester, K. S. 1932. Studies on the precipitin reaction in plants. 1. The specificity of the normal precipitin reaction. Jour. Arnold Arbor. **13**: 52–74.

East, E. M. 1931. Possible immunological reactions in plants. Harvey Lectures **1930–1931**: 112–128.

————. 1931. Immunity to sugar cane mosaic acquired by the host. Proc. Nat. Acad. Sci. **17**: 331–334.

Gheorghiu, J. 1932. L'immunité et la vaccinothérapie anticancéreuse chez les plantes. C. R. Soc. Biol. Paris **109**: 1387–1389.

Heinricher, E. 1929. Allmähliches Immunwerden gegen Mistelbefall. Planta **7**: 165–173.

Hiltner, L. and Stormer, K. 1903. Neue Untersuchungen über die Wurzelknöllchen der Leguminosen und deren Erreger. Arb. Biol. Ab. f. Land. u. Forstwirtschaft. Am. K. Gesundheitsamte **3**: 151–307.

Hursh, C. R. 1924. Morphological and physiological studies on the resistance of wheat to *Puccinia graminis tritici* Erikss and Henn. Jour. Agr. Res. **27**: 381–411.

Jarach, M. 1932. Sul meccanismo dell' immunità acquisita attiva nelle piante. Phytopath. Zeitschr. **4**: 315–327.

Kostoff, D. 1928. Induced immunity in plants. Proc. Nat. Acad. Sci. **14**: 236–237.

————. 1929. Acquired immunity in plants. Genetics **14**: 37–77.

Leemann, A. C. 1932. The problem of active plant immunity. Zentralbl. Bakt. II, **85**: 360–376.

Magrou, J. 1921. Symbiose et tubérisation. Ann. Sci. Nat. Bot. 10e Sér. 3: 181–296.

Montemartini, L. 1930. Est-ce que l'on va vers une immunisation des chênes contre l'Oïdium? Boll. Soc. Intern. Microbiol. Sez. Ital. 2(8): 349–350.

————. 1931. La patogenesi delle malattie delle piante. Report to the Third Congress of the Internat. Microbiol. Soc. Italian Section.

Nobécourt, P. 1928. Contribution à l'étude de l'immunité chez les végétaux. Baillier ed. Tunis.

Ray, J. 1901. Cultures et formes atténuées des maladies cryptogamiques des végétaux. C. R. Acad. Sci. Paris **133**: 307.

Sieden and Trieschmann. 1926. Ein neuer Weg zur Bekämpfung des Kartoffelkrebses? Mitt. Deut. Landwirtsgesell. No. 42.

Silberschmidt, K. 1931. Studien zum Nachweis von Antikörpern in Pflanzen. Planta **13**: 114–168.

Zoja, A. 1925. L'immunità nelle piante. Atti R. Inst. Botanico Univ. di Pavia **2**: (Ser. 3): 15–47.

INDEX TO AMERICAN BOTANICAL LITERATURE

1932–1933

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

This index is reprinted monthly on cards, and furnished in this form to subscribers at the rate of three cents for each card. Selections of cards are not permitted; each subscriber must take all cards published during the term of his subscription. Correspondence relating to the Index may be addressed to the Treasurer of the Torrey Club.

Abbott, E. V. Physiologic forms of *Colletotrichum falcatum* Went Phytopathology **23**: 557–559. Je 1933.

Aikman, J. M. The micro-climate of *Zea Mays* in central Iowa. Proc. Iowa Acad. Sci. **38**: 73–83. *f. 1–3.* [1933.]

Allen, R. F. The spermatia of flax rust, *Melampsora lini*. Phytopathology **23**: 487. My 1933.

Ames, O. An addition to the genus *Epidendrum*. Harvard Bot. Mus. Leafl. 7: 1–4. *illust.* 24 Ap 1933.

Ames, O. Additional notes on the orchids of the New Hebrides and Santa Cruz Islands. Jour. Arnold Arbor. **14**: 101–112. Ap 1933.

Ames, O. A new *Epidendrum* from Honduras. Harvard Bot. Mus. Leafl. 8: 1–5. *illust.* 14 Je 1933.

Anderson, E. Variation in flower color in *Hamamelis vernalis*. Jour. Arnold Arbor. **14**: 253–257. *f. 1.* Jl 1933.

Anderson, J. E. The genetics and cytology of two fifteen-chromosome mutants from the haploid of *Oenothera franciscana*. Am. Jour. Bot. **20**: 387–414. *pl. 22–26.* 15 Je 1933.

Arnold, C. A. A sphenopterid fructification from the Pennsylvania of Michigan. Bot. Gaz. **94**: 821–825. *f. 1–3.* 15 Je 1933.

Arthur, J. C. Authority for the name *Cronartium ribicola*. Phytopathology **23**: 559–561. Je 1933.

Backeberg, C. Brief van den Cactusjager. Succulenta **15**: 110–115. Je 1933.

Backeberg, C. Genus *Binghamia*. Jour. Cactus & Succ. Soc. Am. **4**: 387–388. Je 1933.

Bailey, W. M. Structural and metabolic after-effects of soaking seeds of *Phaseolus*. Bot. Gaz. **94**: 688–713. *f. 1–3.* 15 Je 1933.

Barnett, H. L. Some edible and poisonous mushrooms of North Dakota. N. Dakota Agr. Exp. Sta. Bull. 270: 1–32. *f. 1–34.* Je 1933.

Baskerville, E. Some misunderstood slime-mold species. Proc. Iowa Acad. Sci. **38**: 103–114. *pl. 1, 2.* [1933.]

Belling, J. Crossing over and gene rearrangement in flowering plants. Genetics **18**: 388–413. *f. 1–6.* Jl 1933.

Benedict, R. C. The hart's tongue in three continents. Am. Fern Jour. **23**: 63–64. Ap-Je 1933.

Benner, W. M. The flora of Bucks County, Pennsylvania. Contr. Lab. Univ. Pennsylvania 10: 1–331. 1933.

Bequaert, J. C. Botanical notes from Yucatan. Carnegie Inst. Washington Publ. 431: 505–524. 1933.

Berry, E. W. Fossil plants from Morrison, Colorado. Jour. Washington Acad. Sci. **23**: 308–312. *f. 1.* 15 Je 1933.

Berry, W. Flora in the roof of the Upper Freeport coal at Callahan's mine, Teegarden, Ohio. Ohio Jour. Sci. **33**: 208–209. My 1933.

Bessey, E. A. Sex problems in hemp. Quart. Rev. Biol. **8**: 194–200. Je 1933.

Bisby, G. R., James, N., & Timonin, M. Fungi isolated from Manitoba soil by the plate method. Canadian Jour. Sci. **8**: 253–275. *f. 1, 2.* 1933.

Blake, S. F. A unilaterally fertile frond of *Dryopteris thelypteris*. Am. Fern Jour. **23**: 67–68. *pl. 3.* Ap-Je 1933.

Blake, S. F. *Wolffiella lingulata* in Louisiana. Rhodora **35**: 226. 9 Je 1933.

Bödecker, F. *Echinocactus Borchersii* Böd. sp. n. 1933. Kakteenkunde **1933**: 112. *illust.* Je 1933.

A plant from Peru.

Bödeker, F. *Mamillaria Brauneana* Böd. sp. n. 1933. Kakteenkunde **1933**: 113–114. *illust.* Je 1933.

From Mexico.

Bradford, F. C., & Joley, L. Infectious variegation in the apple. Jour. Agr. Res. **46**: 901–908. *f. 1.* 15 My 1933.

Brentzel, W. E. Physiologic specialization of *Tillitia Tritici* on emmer. Phytopathology **23**: 483–485. *f. 1, 2.* My 1933.

Bressman, E. N., & Nichols, R. A. Germination of the oospores of *Pseudoperonospora humuli*. Phytopathology **23**: 485–487. My 1933.

Brierley, P. Studies on mosaic and related diseases of dahlia. Contr. Boyce Thompson Inst. **5**: 235–288. *f. 1–16.* Ap-Je 1933.

Briton-Jones, H. R. Stripe disease of corn (*Zea Mays* L.) in Trinidad. Jour. Imp. Coll. Trop. Agr. **10**: 119–122. *f. 1–7.* My 1933.

Britton, N. L. Arthur Hollick. Jour. N. Y. Bot. Gard. **34**: 121–124. *portrait.* Je 1933.

Broadhurst, J. Observations on amorphous phase of bacteria. Jour. Bact. **25**: 545–562. *pl. 1–3.* Je 1933.

Brooks, S. C. Accumulation of ions by living cells. Nature **132**: 97–98. 15 Jl 1933.

Brown, A. H. Effects of sulphuric-acid delinting on cotton. Bot. Gaz. **94**: 755–770. *f. 1–4.* 15 Je 1933.

Brown, N. E. *Stapelia semota* n. sp. Jour. Cactus & Succ. Soc. Am. **4**: 393–394. *illust.* Je 1933.

Buller, A. H. R. Fungi in their relations with trees. Proc. Dedication Morris Arbor. 13–25. 2 Je 1933.

Burk, M. M. J. Flowering plants of Black Hawk County, Iowa. Proc. Iowa Acad. Sci. **38**: 135–149. [1933.]

Burkart, A. Dos nuevas compuestas del género *Chaptalia* con una sinopsis de las especies argentinas del mismo género. Physis **11**: 100–106. *f. 1, 2.* 31 D 1932.

Camp, W. H. Distribution and flowering in *Wolffia papulifera.* Ohio Jour. Sci. **33**: 163. My 1933.

Campbell, D. H. The flora of the Hawaiian Islands. Quart. Rev. Biol. **8**: 164–184. Je 1933.

Cavanagh, L. M. Notes on Iowa mosses. IV. Proc. Iowa Acad. Sci. **38**: 129–132. [1933.]

Chapman, A. G. Some effects of varying amounts of nitrogen on the growth of tulip poplar seedlings. Ohio Jour. Sci. **33**: 164–181. *f. 1–7.* My 1933.

Chapman, F. B. Notes on a collection of Myxomycetes from southeastern Michigan. Ohio Jour. Sci. **33**: 205–207. My 1933.

Chester, K. S. The problem of acquired immunity in plants. Quart. Rev. Biol. **8**: 129–154. Je 1933.

Clover, E. U. *Astrophytum asterias* in the United States. Desert **5**: 20–21. Je 1933.

Clover, E. U. The habitat of *Astrophytum asterias* in Texas. Rhodora **35**: 224–225. 9 Je 1933.

Cockerell, T. D. A. A fossil golden rod. Torreya **33**: 72. *illust.* My-Je 1933.

Cook, M. T. Life history of *Ligniera* (*Plasmodiophora*) *vascularum.* Internat. Soc. Sugar Cane Tech. Bull. **31**: 1–3. Mr 1932.

Cook, M. T. The parasitism of *Marasmius Sacchari* Wakker. Internat. Soc. Sugar Cane Tech. Bull. **32**: 1–4. *illust.* Mr 1932.

Costello, D. F. Preliminary reports on the flora of Wisconsin.

XXIII. Urticaceae. Trans. Wisconsin Acad. Sci. **28**: 191–196. *f. 1–12*. 1933.

Cratty, R. I. The Iowa flora. An annotated list of the ferns, fern allies, and the native and introduced flowering plants of the State represented in the Iowa State College herbarium. Iowa St. Coll. Jour. Sci. **7**: 177–252. Ap 1933.

Curtis, O. F., & Scofield, H. T. A comparison of osmotic concentrations of supplying and receiving tissues and its bearing on the Münch hypothesis of the translocation mechanism. Am. Jour. Bot. **20**: 502–512. 19 Jl 1933.

C[utak], L., Ceropegias. Missouri Bot. Gard. Bull. **21**: 95–96. *pl. 21*. Je 1933.

Davidson, A. M., & Gregory, P. H. Development of fuseaux, aleuriospores, and spirals on detached hairs infected by ringworm fungi. Nature **131**: 836–837. 10 Je 1933.

Davidson, R. W., & Cash, E. K. Species of *Sclerotinia* from Grand Mesa National Forest, Colorado. Mycologia **25**: 266–273. *pl. 36–38*. 1 Au 1933.

Davis, B. M. The genetics and cytology of a tetraploid from *Oenothera Franciscana* Bartlett. Genetics **18**: 293–322. *pl. 1–3+f. 1–3*. Jl 1933.

Denny, F. E. Bases for calculations in measuring changes in leaves during the night. Contr. Boyce Thompson Inst. **5**: 181–194. *f. 1–3*. Ap-Je 1933.

Dermen, H. Origin and behavior of the nucleolus in plants. Jour. Arnold Arbor. **14**: 282–323. *pl. 64–67*. Jl 1933.

Doutt, M. T. First record of *Drosera* in Wyoming. Torreya **33**: 93–94. Jl-Au 1933.

Drescher, A. A. Preliminary reports on the flora of Wisconsin. XXII. Cornaceae—dogwood family. Trans. Wisconsin Acad. Sci. **28**: 187–190. *f. 1–8*. 1933.

Drechsler, C. Several more fungi that prey on nematodes. Jour. Washington Acad. Sci. **23**: 355–357. *f. 16–18*. 15 Jl 1933.

Eames, E. H. A new *Ludvigia* from New England. Rhodora **35**: 227–230. 3 Jl 1933.

East, E. M. Genetic observations on the genus *Linaria*. Genetics **18**: 324–328. Jl 1933.

East, E. M., & White, B. The reactions of *Halicystis* and of *Valonia* to injections of certain proteins. Jour. Gen. Physiol. **16**: 937–945. 20 Jl 1933.

East, E. M., & White, B. Reactions of *Valonia* and of *Halicystis* to colloids. Jour. Gen. Physiol **16**: 925–935. 20 Jl 1933.

Endo, S. The American white walnut or butternut, *Juglans*

cinerea L., from the Upper Pliocene of Japan. Jour. Washington Acad. Sci. **23**: 305–308. *f. 1–9.* 15 Je 1933.

Evans, C. R. Germination behavior of *Magnolia grandiflora.* Bot. Gaz. **94**: 729–754. 15 Je 1933.

Farr, W. K. Cotton fibers. III. Cell divisions in the epidermal layer of the ovule subsequent to fertilization. Contr. Boyce Thompson Inst. **5**: 167–172. *f. 1, 2.* Ap-Je 1933.

Fassett, N. C. Preliminary reports on the flora of Wisconsin. XXI. Geraniales. Trans. Wisconsin Acad. Sci. **28**: 171–186. *f. 1–30.* 1933.

Fernald, M. L. Recent discoveries in the Newfoundland flora. Rhodora **35**: 120–140. *pl. 239–242.* 5 Mr 1933; 161–185. *pl. 243–245.* 5 My 1933; 203–223. *pl. 246–248.* 9 Je 1933; 230–247. *pl. 249–254+f. 1.* 3 Jl 1933; 265–283. *pl. 256–260.* Au 1933.

Fernald, M. L. Types of some American species of *Elymus.* Rhodora **35**: 187–198. 9 Je 1933.

Fernald, M. L. The slender-spiked *Spartina pectinata.* Rhodora **35**: 258–260. 3 Jl 1933.

Fisher, M. C. A comparative morphological study of certain species of the Dacryomycetaceae. Proc. Iowa Acad. Sci. **38**: 115–125. *pl. 1, 2.* [1933.]

Freeland, R. O. Some morphological and physico-chemical changes accompanying proliferation of *Bryophyllum* leaves. Am. Jour. Bot. **20**: 467–480. *pl. 31, 32.* 19 Jl 1933.

Freeman, C. P. Ecology of the Cedar Glade vegetation near Nashville, Tennessee. Jour. Tennessee Acad. Sci. **8**: 141–228. *f. 1–22.* Ap 1933.

Frolik, A. L., & Keim, F. D. Native vegetation in the prairie hay district of north central Nebraska. Ecology **14**: 298–305. Jl 1933.

Frye, E. M. *Romanzoffia sitchensis.* New Flora & Silva **5**: 274–275. *f. 96.* Jl 1933.

Gates, H. E. New Neomammillarias from lower California. Jour. Cactus & Succ. Soc. Am. **4**: 371–372. My 1933.

Hanna, L. A. Historical notes and effects of grazing. Torreya **33**: 90–92. Jl-Au 1933.

Hanson, H. C., & Rudd, V. E. Leafy spurge. Life history and habits. North Dakota Agr. Exp. Sta. Bull. 266: 1–24. *f. 1–21.* Mr 1933.

Hansen, H. N., & Smith, R. E. A bacterial gall disease of the Douglas fir. Science II. **77**: 628. 30 Je 1933.

Harland, S. C., & Atteck, O. S. The inheritance of self-sterility in *Petunia violacea.* Genetica **15**: 89–102. 1933.

Harper, R. A. Plant science in the service of art. Proc. Dedication Morris Arbor. 26–41. 2 Je 1933.

Also in Jour. N. Y. Bot. Gard. **34**: 185–198. S 1933.

Harris, S. K. Notes on the flora of Haverhill, Massachusetts. Rhodora **35**: 261–262. 3 Jl 1933.

Harris, S. K. An undescribed *Mutisia* from Ecuador. Rhodora **35**: 257–258. 3 Jl 1933.

Hatch, A. B., & Hatch, C. T. Hymenomycetes forming mycorrhizae with *Pinus Strobus* L. Jour. Arnold Arbor. **14**: 324–334. *pl. 68–71.* Jl 1933.

Hazard, J. O. The trees of the Reelfoot Lake region. Jour. Tennessee Acad. Sci. **8**: 55–60. *f. 19–22.* Ja 1933.

Henry, L. K. Mycorhizas of trees and shrubs. Bot. Gaz. **94**: 791–800. *f. 1–6.* 15 Je 1933.

Hilpert, F. Eine neue Laubmoosgattung. Hedwigia **73**: 68–70. *illust.* 30 Mr 1933.

Pseudohyophila peruviana.

Hoggan, I. A. Some viruses affecting spinach, and certain aspects of insect transmission. Phytopathology **23**: 446–474. *f. 1–5.* My 1933.

Hunnewell, F. W. A further note on *Ophioglossum Engelmanni* in Virginia. Am. Fern Jour. **23**: 66. Ap-Je 1933.

Hurd-Karrer, A. M. Comparative responses of a spring and a winter wheat to day length and temperature. Jour. Agr. Res. **46**: 867–888. *f. 1–9.* 15 My 1933.

Huskins, C. L., & Hearne, E. M. Meiosis in asynaptic dwarf oats and wheat. Jour. Royal Micros. Soc. **53**: 109–117. *pl. 1–4.* Je 1933.

Jeffrey, E. C. Internal chromosomal variation and its probable cause. Science II. **78**: 34–35. 14 Jl 1933.

Jenkins, A. E. A *Sphaceloma* attacking navel orange from Brazil. Phytopathology **23**: 538–545. *f. 1.* Je 1933.

Jenkins, A. E., & Fawcett, H. S. Records of citrus scab mainly from herbarium specimens of the genus *Citrus* in England and the United States. Phytopathology **23**: 475–482. *f. 1.* My 1933.

Kelso, L. A. A note on *Glyceria neogaea* Steudal. Rhodora **35**: 225–226. 9 Je 1933.

Killough, D. T., & Horlacher, W. R. The inheritance of virescent yellow and red plant colors in cotton. Genetics **18**: 329–334. Jl 1933.

Knowlton, C. H. The flora around Missisquoi Bay, Quebec. Rhodora **35**: 247–252. 3 Jl 1933.

Kohl, E. J. An explanation of the cause of spiral grain in trees. Science II. **78**: 58–59. *f. 1.* 21 Jl 1933.

Kramer, P. J. The intake of water through dead root systems and its relation to the problem of absorption by transpiring plants. Am. Jour. Bot. **20**: 481–492. 19 Jl 1933.

Kriebel, R. M. *Asplenium ebenoids* R. R. Scott in Lawrence County, Indiana. Am. Fern Jour. **23**: 52–59. *illust.* Ap-Je 1933.

Lachmund, H. G. Method of determining age of blister rust infection on western white pine. Jour. Agr. Res. **46**: 675–693. *f. 1.* 15 Ap 1933.

Lauritzen, J. I., Harter, L. L., & Whitney, W. A. Environmental factors in relation to snap-bean diseases occurring in shipment. Phytopathology **23**: 411–445. *f. 1–4.* My 1933.

Leach, J. G. A destructive *Fusarium* wilt of muskmelons. Phytopathology **23**: 554–556. *f. 1.* Je 1933.

Li, L. C. New species and varieties of freshwater algae from China. Ohio Jour. Sci. **33**: 151–155. *pl. 1.* My 1933.

Lindquist, J. C. Sobre la presencia de la *Phytophthora capsici* en la Republica Argentina. Physis **11**: 170–174. *f. 1–3.* 31 D 1932.

Lindstrom, E. W. Fertility variations in tetraploid tomatoes with different genetic origins. Proc. Iowa Acad. Sci. **38**: 85–87. [1933.]

Lindstrom, E. W. Hereditary radium-induced variations in the tomato. Jour. Heredity **24**: 129–137. *f. 1–4.* Ap 1933.

Lindstrom, E. W. Linear order of four genes on the first chromosome of the tomato. Proc. Iowa Acad. Sci. **38**: 133–134. [1933.]

Lloyd, F. E. The carniverous plants—a review, with contributions. Trans. Royal Soc. Canada **27**: 3–67. *pl. 1–16+f. 1–19.* 1933.

Lloyd, F. E. The structure and behavior of *Utricularia purpurea*. Canadian Jour. Res. **8**: 234–252. *pl. 1, 2.* Mr 1933.

Loomis, W. E., & Burnett, K. H. Photosynthesis in corn. Proc. Iowa Acad. Sci. **38**: 150. [1933.]

Lyness, A. S. Notes on the fern flora of Iowa. Am. Fern Jour. **23**: 39–49. Ap-Je 1933.

McAtee, W. L. Some local names of plants. V. Torreya **33**: 81–86. Jl-Au 1933.

McCallan, S. E. A., & Wilcoxon, F. The form of the toxicity surface for copper sulphate and for sulphur, in relation to conidia of *Sclerotinia americana*. Contr. Boyce Thompson Inst. **5**: 173–180. *f. 1–3.* Ap-Je 1933.

MacDougal, D. T., & Working, E. B. The pneumatic system of plants, especially trees. Carnegie Inst. Washington Publ. 441: 1–87. *f. 1–4.* Je 1933.

Macfarlane, J. M., & Steckbeck, D. W. *Sarracenia purpurea* var. *stolonifera.*, a noteworthy morphological and ecological type. Kew Bull. Misc. Inf. **1933**: 161–169. *pl. 10, 11.* 1933.

Mack, W. B., & Livingston, B. E. Relation of oxygen pressure and temperature to the influence of ethylene on carbon-dioxide production and on shoot elongation in very young wheat seedlings. Bot. Gaz. **94**: 625–687. *f. 1–5.* 15 Je 1933.

McKinney, H. H., & Sando, W. J. Earliness and seasonal growth habit in wheat. Jour. Heredity **24**: 169–179. *illust.* My 1933.

McKinney, H. H., & Sando, W. J. Russian methods for accelerating sexual reproduction in wheat. Jour. Heredity **24**: 165–166. Ap 1933.

McNamara, H. C., & Hooton, D. R. Sclerotia-forming habits of the cotton root-rot fungus in Texas black-land soils. Jour. Agr. Res. **46**: 807–819. *f. 1–5.* 1 My 1933.

Marchionatto, J. B. Las helmintosporiosis de la cebada en la República Argentina. Physis **11**: 107–114. *f. 1, 2.* 31 D 1932.

Marshall, W. T. Baja California cacti. Jour. Cactus & Succ. Soc. Am. **4**: 398. Je 1933.

Matschat, C. H. *Cypripedium irapeanum.* Orchid Rev. **41**: 170–171. *illust.* Je 1933.

Matz, J. Artificial transmission of sugarcane mosaic. Jour. Agr. Res. **46**: 821–839. *f. 1.* 1 My 1933.

Melhus, I. E. Some recent contributions to our understanding of corn diseases. Proc. Iowa Acad. Sci. **38**: 89–101. [1933.]

Miller, J. H. Some new species of *Hypoxylon.* Mycologia **25**: 321–329. *pl. 39, 40+f. 1.* 1 Au 1933.

Miller, L. P. Effect of various chemicals on the sugar content, respiratory rate, and dormancy of potato tubers. Contr. Boyce Thompson Inst. **5**: 213–234. *f. 1, 2.* Ap-Je 1933.

Miller, L. W. The genera of Hydnaceae. Mycologia **25**: 286–302. 1 Au 1933.

Mix, A. J. Factors affecting the sporulation of *Phyllosticta solitaria* in artificial culture. Phytopathology **23**: 503–524. *f. 1.* Je 1933.

Moldenke, H. N. A new species of *Vitex* from South America. Torreya **33**: 67–69. My-Je 1933.

Moore, E. J. Growth relations in culture of the cotton-root-rot

organism, *Phymatotrichum omnivorum*. Phytopathology **23**: 525–537. *f. 1, 2*. Je 1933.

Moore, C. N., & Haskins, C. P. Physiological variations in certain crop plants following seed exposure to high-voltage x-rays. Bot. Gaz. **94**: 801–807. *f. 1–6*. 15 Je 1933.

Morton, C. V., & Thompson, J. W. A new *Silene* from Washington. Torreya **33**: 70–71 My-Je 1933.

Neatby, K. W. A chlorophyll mutation in wheat. Jour. Heredity **24**: 159–162. *f. 9, 10*. Ap 1933.

Nelson, R. Some storage and transportational diseases of *Citrus* fruits apparently due to suboxidation. Jour. Agr. Res. **46**: 695–713. *pl. 1–6*. 15 Ap 1933.

Nevins, B. I. Cytological studies on the antheridia of *Sphaerocarpos Donnellii*. La Cellule **41**: 293–334. *pl. 1–3*. 1933.

Norton, A. H. *Rorippa amphibia* in Androscoggin County, Maine. Rhodora **35**: 262. Jl 1933.

Osten, C. Una nueva especie de *Gunnera* del Uruguay: *Gunnera Herteri* Osten n. sp. Physis **11**: 176–178. *f. 1–4*. 31 D 1932.

Palmer, E. J., & Steyermark, J. A. The family Isoëtaceae in Missouri. Am. Fern Jour. **23**: 65–66. Ap-Je 1933.

Parodi, L. R. Algunas Gramineas Argentinas nuevas o criticas. Physis **11**: 129–138. *f. 1–4*. 31 D 1932.

Pearson, G. A. A twenty year record of changes in an Arizona pine forest. Ecology **14**: 272–285. *f. 1–6*. Jl 1933.

Perry, L. M. A revision of the North American species of *Verbena*. Ann. Missouri Bot. Gard. **20**: 239–362. *pl. 13–15*. Ap 1933.

Philp, G. L. Abnormality in sweet cherry blossoms and fruit. Bot. Gaz. **94**: 815–820. *f. 1–5*. 15 Je 1933.

Pomerleau, R. Les Groseilliers du Quebec. Nat. Canadien **60**: 141–153. *f. 1–10*. My 1933.

P[ring], G. H. Curious orchids in the Garden collection. Missouri Bot. Gard. Bull. **21**: 96–99. *pl. 22–24*. Je 1933.

Pugh, G. W., Johann, H., & Dickson, J. G. Factors affecting infection of wheat heads of *Gibberella Saubinetti*. Jour. Agr. Res. **46**: 771–797. *f. 1–12*. 1 My 1933.

Rand, F. V., & Cash, L. C. Bacteria wilt of corn. U. S. Dep. Agr. Tech. Bull. 362: 1–30. *pl. 1–3+f. 1, 2*. My 1933.

Redinger, K. Neue und wenig bekante Flechten aus Brasilien. Hedwigia **73**: 54–67. *f. 1–8*. 30 Mr 1933.

Reed, H. S. La nature de la croissance. Bull. Soc. Bot. Geneve **24**: 202–219. *f. 1–5*. 1933.

Reznik, M. A. Graminées nouvelles ou mal connues de la

Guinée-Francaise. Bull. Mus. Hist. Nat. **4**: 1046–1049. *illust.* D 1932.

Reznik, M. A. Un Ischaemum nouveau pour la Guinée-Francaise. Bull. Mus. Hist. Nat. **4**: 1050–1051. D 1932.

Rigg, G. B. Notes on a Sphagnum bog at Fort Bragg, California. Science II. **77**: 535–536. 2 Je 1933.

Rowntree, L. Tiny annuals of the California desert. Desert **5**: 24–25. *illust.* Je 1933.

Rudorf, G., & Job, M. M. Noticias sobre une bacteriosis en cultivos de alhelies *Matthiola incana* var. *annua*. Physis **11**: 122–127. *f. 1–4.* 31 D 1932.

Rugg, H. G. *Cystopteris montana* in Glacier National Park. Am. Fern Jour. **23**: 66–67. Ap-Je 1933.

Sax, K. Chromosome behavior in *Calycanthus*. Jour. Arnold Arbor. **14**: 279–281. *f. 1.* Jl 1933.

Sax, K. Species hybrids in *Platanus* and *Campsis*. Jour. Arnold Arbor. **14**: 274–278. *f. 1, 2.* Jl 1933.

Schaffner, J. H. *Equisetum kansanum* in Missouri. Am. Fern Jour. **23**: 64. Ap-Je 1933.

Schuh, R. E. *Myriotrichia densa* in New England. Rhodora **35**: 256–257. 3 Jl 1933.

Schwarz, A. J. The cryptogamous plants of Reelfoot Lake. Jour. Tennessee Acad. Sci. **8**: 37–42. *f. 10–12.* Ja 1933.

Shaver, J. M. A preliminary report on the plant ecology of Reelfoot Lake. Jour. Tennessee Acad. Sci. **8**: 48–54. *f. 14–18.* Ja 1933.

Shaw, G. R. Notes on the genus *Pinus*. Jour. Arnold Arbor. **14**: 258. Jl 1933.

Shear, C. L. Life histories of *Tryblidiella* species. Mycologia **25**: 274–285. *f. 1–5.* 1 Au 1933.

Sherbakoff, C. D. A new fungus parasitic on nematodes. Mycologia **25**: 258–262. *pl. 35.* 1 Au 1933.

Smith, F. H. Preliminary studies of chromosome rings in *Brodiaea lactea*. Proc. Washington Acad. Sci. **19**: 605–609. *f. 1–4.* 15 Je 1933.

Smith, H. H. Ethnobotany of the forest Potawatomi Indians. Bull. Publ. Mus. Milwaukee **7**: 1–230. *f. 1–38.* 9 My 1933.

Snyder, J. C. Flower bud formation in the Concord grape. Bot. Gaz. **94**: 771–779. *f. 1–22.* 15 Je 1933.

Soriano, S. Nota sobre algunas enfermedades de los vegetales producidas por virus en la Republica Argentina. Physis **11**: 87–92. *f. 1–3.* 31 D 1932.

Stafford, D. Plant hunting in the Andes of southern Peru. Gard. Chron. **93**: 373. 27 My 1933; 387–388. 3 Je 1933.

S[tapf], O. *Parmianthe peruviana*. Curt. Bot. Mag. **156**: *pl. 9315*. 1 Jl 1933.

Steil, W. N. Incomplete nuclear divisions and not amitosis in the tapetum of the eusporangiate ferns. Science II. **77**: 606–607. 23 Je 1933.

Stevens, O. A. Poisonous plants and plant products. North Dakota Agr. Exp. Sta. Bull. 265: 1–30. *f. 1–20*. Mr 1933.

Summerhayes, V. S. *Physosiphon Lindleyi*. Curt. Bot. Mag. **156**: *pl. 9325*. 1 Jl 1933.

Swartz, D. Some developmental characters of species of Lycoperdaceae. Am. Jour. Bot. **2**: 440–465. *pl. 29, 30*. 15 Je 1933.

Tascher, W. R. Experiments on the control of seed-borne diseases by x-rays. Jour. Agr. Res. **46**: 909–915. 15 My 1933.

Tehon, L. R. Notes on the parasitic fungi of Illinois. Mycologia **25**: 237–257. *pl. 34*. 1 Au 1933.

Thomas, H. E. The quince-rust disease caused by *Gymnosporangium germinale*. Phytopathology **23**: 546–553. *f. 1*. Je 1933.

Thomen, A. A., Hay fever—a study in applied botany. Brooklyn Bot. Gard. Leafl. 21: 1–8. 17 My 1933.

Torrey, R. H. *Parmelia Cladonia*, a beautiful northern lichen, found on Catskill summits. Torreya **33**: 87–89. Jl-Au 1933.

Torrey, R. H. Rock tripes on a Long Island glacial boulder. Torreya **33**: 63–64. My-Je 1933.

Transeau, E. N. The genus *Zygogonium*. Ohio Jour. Sci. **33**: 156–162. *pl. 1, 2*. My 1933.

True, R. H. The Morris Arboretum and its future. Proc. Dedication Morris Arbor. 5–12. 2 Je 1933.

Truscott, J. H. L. Observations on *Lagena radicicola*. Mycologia **25**: 263–265. *f. 1*. 1 Au 1933.

Tullis, E. C. *Ophiobolus oryzinus*, the cause of a rice disease in Arkansas. Jour. Agr. Res. **46**: 799–806. *f. 1*. 1 My 1933.

Voss, J. Pleistocene forests of central Illinois. Bot. Gaz. **94**: 808–814. *f. 1*. 15 Je 1933.

Wadmond, S. C. Notes from southeastern Wisconsin. II. Rhodora **35**: 252–256. 3 Jl 1933.

Wadmond, S. C. The *Quercus ellipsoidalis—Quercus coccinea* complex. Trans. Wisconsin Acad. Sci. **28**: 197–203. *f. 1*. 1933.

Warburg, E. F. *Quercus suchiensis*. Kew Bull. Misc. Inf. **1933**: 188–189. 1933.

A tree from Mexico.

Weier, T. E. Neutral red staining in the protonema of *Polytrichum commune*. Am. Jour. Bot. **20**: 431–439. *pl. 28*. 15 Je 1933.

Wentzel, S. F. Meiosis in *Digitalis ferruginea* with special reference to the anachromatic and catachromatic processes. Am. Jour. Bot. **20**: 493–501. *f. 1–8*. 19 Jl 1933.

Werdermann, E. *Echinocactus Cumingii* Hopffer, *Pilocereus chrysostele* (Vaupel) Werd. Blüh Sukkul. **14**: *pl. 53, 54*. 1933.

Whitaker, T. W. Cytological and phylogenetic studies in the Cucurbitaceae. Bot. Gaz. **94**: 780–790. *f. 1–16*. 15 Je 1933.

Whitehead, J. Desert wild flowers. Torreya **33**: 57–62. My-Je 1933.

Wood, J. I., Stevens, N. E., & Miller, P. R. Diseases of plants in the United States in 1932. Plant Disease Rep. (Suppl.) 85: 1–82. 15 Je 1933.

Wright, Y. *Borzicactus icosagonus*. Jour. Cactus & Succ. Soc. Am. **4**: 394. *illust.* Je 1933.

Wynd, F. L. Nutrient solutions for orchids. Ann. Missouri Bot. Gard. **20**: 363–372. *f. 1–10*. Ap 1933.

Zaumeyer, W. J., & Wade, B. L. Mosaic diseases affecting different legumes in relation to beans and peas. Phytopathology **23**: 562–564. Je 1933.

Zimmerman, P. W., Crocker, W., & Hitchcock, A. E. The effect of carbon monoxide on plants. Contr. Boyce Thompson Inst. **5**: 195–211. *f. 1–7*. Ap-Je 1933.

RECENT PUBLICATIONS OF THE TORREY BOTANICAL CLUB

BOTANICAL results of the Tyler-Duida expedition, by H. A. Gleason, with the assistance of numerous collaborators. Reprinted from Bulletin of The Torrey Botanical Club, vol. 58. 230 pages, 29 plates, 8 figures, folding map, and special index. 1931. $2.00.

Present evolutionary tendencies and the origin of life cycles in the Uredinales, by Herbert S. Jackson. Memoirs of The Torrey Botanical Club, vol. 18, no. 1. 108 pages. 1931. $2.00.

The genus Cuscuta, by Truman George Yuncker. Memoirs of The Torrey Botanical Club, vol. 18, no. 2. 220 pages. 158 figures, and chart. 1932. $4.00.

Volume 18 of the Memoirs complete, comprising the two above parts, with title-page. 331 pages. $5.00.

For further information about the Club's publications, address Mrs. R. A. Harper, Schermerhorn Hall, Columbia University, New York, N.Y.